Richardson, E.C.   Home-made and improvised apparatus and materials in
1936   general science instruction.

BOSTON UNIVERSITY
SCHOOL OF EDUCATION

Thesis

Home-made and Improvised Apparatus and Materials in General Science Instruction

Submitted

by
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(B.S., Massachusetts State College, 1929)

In partial fulfillment of requirements
for the degree of Master of Education

1936

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Contents

CHAPTER III (continued). Page

List of Figures

List of Tables

CHAPTER I

INTRODUCTION

The Problem

A. <u>Stating the problem</u>.

The purpose of this study is to collect and present in organized fashion the many varieties of simple procedure which may be used in developing the principles of general science.

In today's general science textbooks a large number of procedures are suggested--procedures such as demonstrations, projects, home experiments, reports, or nature observations. The value of these suggestions will depend upon the extent to which they meet certain requirements of practicability. Usually in a given class only a few of these suggestions are developed. Those procedures requiring materials that are at hand, and which the teacher believes will produce satisfactory results when put to use, are the ones that would most likely be used. The others, because of a lack of necessary materials, because of the expense involved, because of the amount of time required, because of the lack of available information, or because of any one of a variety of other reasons, are

likely to be omitted. An inexperienced teacher, particularly, would tend to select those experimental plans which seemed as simple and as promising of effectiveness as possible. More experienced teachers having "pet" procedures which, for the most part, carry over from year to year, would welcome simple, promising demonstrations if for no better reason than to break the monotony of the habitual response to a particular situation. In view of these assumptions it can be stated again that the purpose of this study is to search out the simplest, the most commonplace, and the least expensive types of apparatus and materials necessary to the development of a given principle of science, and to present as large a variety of procedures as possible. Little has been done in this line of endeavor, and apparently, a need for this type of research is felt. To quote a communication from Morris Meister, Head of the Science Department at the Haaren High School in New York City, Professor of Education of the New York Teachers' Training College, and at City College of New York, Editor of the _Science Classroom_, and author of several general science textbooks:

> "Your proposed study is an excellent one and its conclusions will be of great practical use. As far as I know, such has never been assembled in a thorough-going way."

B. _Classroom illustrations of the problem_.

The science instructor is frequently reminded by the pupils

themselves that home-made apparatus may often serve as useful a purpose as the more orthodox factory-made equipment. For example, one of the writer's pupils in order to make available a current which would flow in but one direction, in the absence of the alternating current rectifier suggested eliminating one phase by hooking a suitable resistance into series with lead and aluminum electrodes in a borax solution covered with a film of oil. On another occasion, when a spring clamp fastened to an upright, and heated at its extended, twisted end, is observed to droop and then fall free, the instructor has had a second opportunity to realize that in some respects his equipment is not as limited in function as he had at first supposed. In both cases very simple materials close at hand could be found useful for the development of an idea. In these two cases certain supply-house equipment, more specifically a battery substitute and the conventional ball and ring (to illustrate the expansion of metals with heating) at costs of $9.50, and $1.20,[1/] respectively, are no longer indispensible.

Perhaps the lesson for the moment is the electric bell. The only thing accomplished by hooking up the batteries, key, and bell with wire, and then operating the key, is the illustration of the necessary parts. The pupils do not understand the current breaker, or the reason for using soft iron in the core, steel in the armature, and brass at the contacts.

1/ Catalogue H351, Central Scientific Company, pp. 605-564.

Or suppose the lesson concerns itself with the radio. Certainly, a switch thrown, dials adjusted, and music heard in no way approaches understanding of the principles involved.

These illustrations lead to the primary contention that operating highly-evolved apparatus from supply houses in the presence of the pupils often may be entertaining yet lacks instructional value.

C. History of the problem.

As long as there have been attempts to instruct people in the principles and applications of natural science, at least since the time of the philosophy of Galileo, there has been the problem of providing illustrative apparatus. The earliest instructors of science subjects had no supply houses to take care of the matter of equipment, and so instruction by experiment, when attempted, of necessity was possible only as the instructor dug out the experiments of the explorers of science. Had one of Thomas Edison's early assistants turned teacher, and, acting in that capacity, attempted to develop the concepts and understandings associated with an electric light bulb, he would have had to use the materials which led to the invention of the first electric light bulbs. There would have been no alternative; no supply house to furnish him catalogue pieces. The history of scientific research (in its record of trial and error) suggests the source of the most valuable material to use as equipment with which to evolve understanding in science.

It is worthwhile to reflect that the explorers in the fields of natural science provided their own apparatus and materials for experiments. Actual discoveries of principles and of their applications came from the use of the commonplace type of equipment. Our myths tell us that Newton needed only the impulse of a falling apple to crystallize the concept of gravitation. Edison used carbonized threads of any material that could be spun into fiber, material such as rags, cork, bamboo, and paper, or grain and other plant fibers, to find a suitable filament for his incandescent bulb.

It would seem that all experimental activities basic to the comprehension of principles in science are those which fall within the student's present experience. History shows that the discovery of principles comes as a result of the use of home-made types of apparatus. This suggests the use of such types with which to instruct others.

D. Necessity of solution.

It might be said that there is no problem in securing the apparatus and materials necessary to develop scientific principles--that commercial organizations (as evidenced by the encyclopedic size of their catalogs) have met this situation by providing diversity as well as quantity in their types of equipment. Complete dependence upon supply houses, however, is met with several objections. Not the least of these is the matter of expense. Of 114 answers to a letter of inquiry sent to the

high schools of Massachusetts in connection with this study, nine indicated a noticeable lack of equipment, six reported the teaching of the general science subjects with no experiments whatsoever (due to lack of both equipment and laboratory facilities) while only eleven indicated that the problem of providing home-made apparatus for their classes was nonexistent because of appropriations which provided liberal varieties and quantities of apparatus from the supply houses. Incidently, it was interesting to find one school in the state reporting such a fine endowment that any piece of equipment desired could be had and still leave unused part of the annual income. In the light of the returns to this form letter it seems consistent to say first, that most school budgets can not afford a complete supply of factory-made apparatus, and second, that even a sampling of the factory product is too expensive in more cases than we might guess. In addition, the factory-made product is questioned in several ways:

1. What of the boy schooled in a garage or factory who considers the school laboratory models as so many toys, lacking both use and challenge?

2. What of the pupil who, attending school because of the impossibility of getting a job, would much prefer making things with his hands to studying the theory of either the variable resistance box or the electroscope?

3. What of the teacher, a specialist in foreign lan-

guages, Latin, let us say, who, having been assigned a general science period because of the diminished number of classes in her subject, has the fear of incompetence to teach the science and also a dread of the demonstration work with this highly technical equipment?

4. What of the class the very size of which takes the observation of a given piece of apparatus out of the range of vision of many of the pupils?

Although the factory-made product is a model of neatness, compactness, stability, and ease of analysis, these questions involving other characteristics which were not important fifteen years ago, are of considerable weight today. Unfortunately, the answers to these questions provided by examination and use of the factory products are not entirely satisfactory. The compactness of the pieces may handicap persons in remote sections of the science classroom; for the garage boy and the boy inventor there is no challenge; for the Latin teacher it may often be an ordeal; and for all, the use of such is expensive. Factories have come to recognize the need for extra large pieces as is evidenced by the comparatively recent production of apparatus such as an electric motor model and a voltmeter-ammeter both of which have been seen effectively in use with classes of 55 pupils in elementary physics. However, these examples are unusual. Compactness is a marked characteristic of the factory product. It often interferes with

ease of understanding for beginners.

In addition to the characteristics of expense and adaptability of equipment there is another factor which is, perhaps of more importance. Neat, compact, and easily operated apparatus is desirable, but of what benefit are these qualities if the principles involved are not understood? Ease of operation and polish of the equipment can defeat the purpose of the student. Supply houses certainly produce materials to be admired for their shininess, permanence, and readiness for use; but for people just beginning, these excellent qualities do not work to the best advantage. What is the effect of improvised apparatus upon the pupil's understanding of principles? On this point, G. E. Underhill, of the Mary C. Wheeler School in Providence says: 1/ "If a pupil makes a piece of apparatus and it works, he is apt to understand the principle." Meister hints at the same idea in saying: 2/

> "More important than economy is the question of effective techniques in demonstrations... Often a pupil's question can be answered most effectively by suggesting an experiment with simple, easily-obtained, and cheap, or toy, apparatus."

1/ G. E. Underhill, "Home-made Apparatus", General Science Quarterly, March, 1929, p. 182.

2/ Morris Meister, "Recent Educational Research in Science Teaching", School Science and Mathematics, Volume 32, 1932 pp. 881-884. (An address before the All-Science Section of the Wisconsin State Teachers' Association, November 5, 1931, at Milwaukee.)

Evaluating the Sources of Material
for Solution of the Problem

A. Laboratory manuals and textbooks.

For many years textbooks in science have been accompanied by laboratory manuals. Thirty-five years ago, at a time when manufacturers were a negligible source of complex apparatus and materials, the manuals were necessarily filled with experimental procedures requiring little in the way of factory supplies. For example, Woodhull and Van Arsdale, (Woodhull and Van Arsdale, Physical Experiments, a laboratory manual accompanying Textbook of Physics, Henderson and Woodhull, 1900, D. C. Appleton and Company) gives directions for the execution of 188 experimental procedures. All of these were to be carried out with the following list which seems meager:

(1) Materials--water, alcohol, benzine, gasoline, ether, carbon disulphide, mercury, oil, chalk, sugar, salt, wax, candles, oxygen, hydrogen, goldbeater's skin, ammonium chloride, alum, roll sulphur, copper wire, tin, lead, bronze, phosphorus, magnetite, starch, postassium iodide, German silver wire, cardboard, soap, and rubber dam.

(2) Apparatus--glass plates, tubes, rods, flasks, tumblers, cylinders, wide-mouth bottles, lamp chimney, test tubes, and lenses, convex and concave; wooden blocks, bars; rubber bands, tubing, and stoppers; cork stoppers; thermometers, Fahrenheit and Centigrade; spring balances; metallic gauze, cup; needles; compass; pith balls; heat source; dowel rod; watch; nails and spikes; mirrors, plane and curved; galvanometer, and voltmeter-ammeter.

Evidently schools at this time needed but a small amount of materials for laboratory work. Considering the statement

that this list represented the necessary different materials for nearly two hundred experiments, it is a good example of the limited extent to which factory-made products should be regarded as absolutely essential.

Examination of more recent manuals shows that the textbook writers in greater degree than ever before depend upon the factory facilities for the different supplies used in classroom experimentation. A comparison of the manuals of today with those of twenty-five years ago brings to light three major trends, which are: The manual has become more of a supplement to the text than an independent laboratory guide. It details fewer experiments. The manual's list of needs is more highly specialized. Wholesome progress explains some of this change, yet it is believed that the availability of ever-better apparatus at the supply houses has resulted in undue dependence upon this source. It seems that the textbook writers may have been relying too much on the apparatus makers not only to design equipment, but to suggest the procedures for which their constructions seem most serviceable. If this is true, then these manuals become a meager source of original methods. However, two exceptions to this generality have been met: Physical Experiments by Woodhull and Van Arsdale, and Laboratory Projects in Physics by F. F. Good.

B. General-science textbooks.

In a limited sense each science textbook is in part the

result of a selective survey of the experimental procedures in use for evolving a particular principle. A considerable number of the adopted procedures involve the use of apparatus which is accessible in most laboratories. Such texts are important to this study. With the emphasis placed increasingly upon the "everyday" and the "environmental" aspects of experience for study, the more recent texts are particularly important.

Apparently, however, there have been few attempts to publish source books or to present courses of study for teachers, either in the field or in training, in which the guiding principle was self-sufficiency in providing one's own apparatus. As recently as November, 1931, Meister[1/] indicated that:

> "There is a great need of a single source book to which teachers of science could refer and in which they could find helpful suggestions about possible apparatus experiences for each important topic of the courses in science."

There are endless publications listing apparatus methods in some special field, as for example, handbooks used by people following the activities of some special hobby field such as electricity, radio, mechanics, or chemistry. The Boy-Scout Handbook, books of magic, and the like, cover interesting though not necessarily instructive ideas. An example of an idea of worth is that found in the Boy-Scout Handbook describing the use of a watch as a direction finder,

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1/ Meister, see previous note, p. 881.

or compass; and an example of an idea of less value is that in the book of magic describing how to amuse and mystify one's friends by effecting the various color changes possible with the different water-solution mixing process.

Fifteen years ago the general science book merely skimmed material which the pupil would probably contact in any science courses he might take later in his high-school years. This text would be composed of a selection of the simpler subject matter and experimental activities from the specialized science subjects such as biology, chemistry, and physics. In addition, a limited amount of material from the more specialized subjects of physical geography, geology, and astronomy would have been included. In recent years three influences have been operating to make the general science text an improved source of improvised procedures. As was said a moment ago, there is now an increasing emphasis upon the "everyday" experiences of the youngsters. It is an attempt to correlate school study with the situations which the pupils face, and back of this is the ideal that, since the pupil comes first, the factual matter is but the means to the end. Thus the science of the pupil's life comes in for major consideration. The emphasis fifteen years ago of presenting in quantity the principles of the more advanced sciences is thereby removed. Accordingly, those activities which are chosen by the writers for their books recognize this change

in the philosophy of general science in the degree that the apparatus and materials required come from the pupil's surroundings. Thus, in the recent general science texts there is more material which would bear on the subject of improvised apparatus. However, textbook writers even in general science tend to adapt their prescriptions to the supplies available at the factory, thereby giving little exercise to their own ingenuity, making little provision for the exercise of the pupil's ingenuity, and, in so doing, failing to recognize that the people who have to read their writings are beginners in the subject. Likewise, there is enough repetition to give rise to the suspicion that a so-called "new edition" is the same old book with a new cover and a slightly different arrangement of materials. Nevertheless, it is a fact that the changed emphasis is responsible for an improvement in the texts as a source of home-made apparatus.

As an outgrowth of the emphasis toward the "everyday" aspects of science for study, the curriculum makers have been in favor of shifting the general science program downward to occupy a place in the earlier training of the individual. If general science experiments are to be done in the elementary school, they must be simplified. Experiences with meaning to pupils of the elementary school are limited in number. This trend, alone, from a psychological view would demand the use of the simplest as well as the commonplace materials.

The third influence operating to simplify textbooks has been the wider spread of the "activity" philosophy. Projects, home activities, and experiments now occupy a place more important than formerly in the make-up of the books. In the first place much more space is devoted to activities at the sacrifice of space for information, and secondly, the activities are outlined or explained first in order, while the factual matter follows.

Because of the influence of the movement toward the philosophy of learning by doing, because of the tendency to introduce science subjects at an earlier age level, and because of shift in emphasis from the factual to the student, the modern text proves a fruitful source of suggestions to teachers who seek to improvise or to make at home or in the shop, the materials or equipment for demonstration and experiments.

C. <u>"Popular" and professional magazines</u>.

A wealth of material, widely scattered and uncorrelated, is stored away in popular and professional magazines. The term "popular" refers to publications like <u>Scientific American</u>, <u>Popular Science</u>, <u>Science and Invention</u>, and <u>Radio Journal</u>. Activities to be carried out in the home workshop are included in these magazines. In these sources some striking and novel methods of real value will be found. For example, to show that water is a poor conductor of heat one finds the sug-

gestion to expose the bulb of an air thermometer to a layer of burning gasoline a half-inch of water intervening between the bulb and the flame. Such a suggestion is obviously effective, simple, challenging, and practical.

The publications classed as "professional" include monthly, weekly, or quarterly publications such as the following: The School Science Review[1], School Science and Mathematics[2], Journal of Chemical Education[3], General Science Quarterly[4], The Science Classroom[5], Science News Letter[6], and Current Science[7]. These publications include articles relating to recent advances in applied and theoretical science as reported from the various fields of research, and also, there are contributions of experimental procedures reported by teachers who

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1/ The School Science Review, a quarterly magazine for science teachers published for the Science Masters' Association and the Association of Women Science Teachers, by John Murray, Albermarle Street, London. Volume 1 appeared October, 1919.

2/ School Science and Mathematics, a journal for all science and mathematics teachers, published by the Central Association of Science and Mathematics Teachers.

3/ Journal of Chemical Education, published by the Chemical Education division of the American Chemical Society, Easton, Pennsylvania.

4/ General Science Quarterly, by W. G. Whitman, Editor, and Publisher, Salem, Massachusetts.

5/ The Science Classroom, a monthly guide for science teachers, edited by Morris Meister, and copyrighted by Popular Science Publishing Company, Incorporated, Volume 1 in 1930.

6/ Science News Letter.

7/ Current Science, a weekly for pupils and teachers in general science subjects.

feel that the suggestions might find application in classes similar to their own. These experimental notes on procedure are, for the most part, original with the reporting teachers, or occasionally, the idea will have found its beginnings in the mind of a pupil. Apparently, most of these have, before submission for publication, received trial in classroom work. Hence, there should be much in these magazines of value in this investigation.

D. Teacher experience.

Perhaps the most fruitful source of information is to be found by actual contact with teachers who for various reasons are interested in the possibilities of the home-made type of apparatus. It is from this group, who have been improvising apparatus and developing special techniques and skills for some phase of their actual classroom work, that most worthwhile suggestions should come.

E. Miscellaneous sources of Information.

In addition, several other sources of information have contributed definitely to this report. In the records of educational research one thesis was found on the subject. C. H. Lombard[1/], at the Boston Teachers' College, in 1933, listed 20 experiments as exercises in high-school physics in which the home-made or improvised materials of the shop might be used. Examination of these ideas included in this thesis

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1/ C. H. Lombard, Home-made Apparatus, Boston Teachers' College, 1933.

results in the belief that many teachers are likely to find use for them.

The only source book discovered, The Science Masters' Book,[1] is usually inaccessible. Its preface explains its nature:

> "Since the School Science Review was started in June, 1918, notes on Apparatus and Experiments have been a fairly constant feature, and this book is the natural outcome. Besides contributions from members of the Science Masters' Association, many have been attained directly or indirectly, from University teachers--directly in the form of articles and notes to the School Science Review indirectly in the form of demonstrations given at the annual meetings of the Association... The book is necessarily a scrap book..."

These experiments listed in the two volumes can be performed with inexpensive and shop-work materials. They range in application from the simplest to the more specialized of scientific phenomena, and are worked up in such a manner as to be possible of completion with a minimum of apparatus plus some teacher effort.

Another source of this type of information is found in a reference in the General Science Quarterly of March, 1929, in an article "home-made" Apparatus,[2] reported by Doctor G. E. Underhill, in which he writes of a course he gave at the

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1/ The Science Masters' Book, Volumes 1 and 2, being experiments selected from the School Science Review by a committee of the Science Masters' Association, edited and arranged by G. H. J. Adlam, M. A., B. Sc., published by John Murray, Albermarle Street, London, West.

2/ Underhill, op. cit., p. 178

Hampton Institute Summer Session in 1928, and in which the main objective was to learn to make one's own set ups for laboratory demonstrations.[1]

There are therefore many other sources of data for the solution of this problem any of which could provide very definite material of value to science teachers. These are: recent and older laboratory manuals, hobby books, general science textbooks, publications of the "popular" and professional types, a limited number of theses and pulications, one course (now discontinued) for the training of teachers in the construction of their own apparatus, and of most importance, the teachers themselves who because of some particular conditions or ideas have encouraged and experimented with possibilities in the field of home-made and improvised apparatus.

Sources and Presentation
of Materials Selected

A. Sources sampled but not completely analyzed.

In this study a number of recent general science manuals and workbooks were scanned as possible sources of data. Superficial examination, however, indicated that the authors employ the text as a means of expanding upon the experimental procedures referred to in the book. Hence one might expect to find very little additional data from an analysis of the manual

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1/ Communication with Mr. Aery, director of the Summer Session, indicates that Doctor Underhill is no longer at the Wheeler School, and reports the address of 37 Hillcrest Avenue, New Britain, Connecticut.

if one had already examined the text.

"Hobby" books and the "popular" science magazines were found to be good sources. The details of steps necessary to put together a home-made telescope, or the simple test usable in the classification of rock specimens represents the absorbing type of activity suggested. The number of scientific hobby books is large, and so likewise, is the list of the "popular" science magazines. To analyze them requires more time than is available for the completion of this report. However, Popular Science for four months, and School Science and Mathematics for three years were carefully studied. Extracts were made from each set. Otherwise, this type of literature was scanned only.

B. Sources analyzed in detail.

Eleven of the general science texts used and published during the last fourteen years, and the opinions and suggestions of 114 teachers and supervisors in action today in the public high schools of Massachusetts comprise the main sources of this study. Ten of these texts have appeared since 1930. The list follows:

1. The Science of Common Things, Samuel F. Tower and Joseph R. Lunt, D. C. Heath and Company, Boston, 1922.

2. Introduction to Science, Otis W. Caldwell and Francis D. Curtis, Ginn and Company, 1930.

3. The World in Which We Live, Morris Meister, Charles Scribner's Sons, Boston, 1930.

4. Problems in General Science, George W. Hunter and Walter G. Whitman, American Book Company, Boston, 1930.

5. General Science for Today, Ralph K. Watkins and Ralph C. Bedell, MacMillan and Company, New York, 1932.

6. The Science of Everyday Life, Edgar F. Van Buskirk, Edith L. Smith, and Walter F. Nourse, Houghton and Mifflin, Boston, 1933.

7. Everyday Problems in Science, Charles J. Pieper and Wilbur L. Beauchamp, Scott, Foresman and Company, New York, 1934.

8. Our Environment Series, Harry A. Carpenter and George C. Wood, Allyn and Bacon, Boston, 1934.

9. Our Surroundings, Arthur G. Clement, Morton C. Collister, and Ernest L. Thurston, Iroquois Publishing Company, Syracuse, New York State, 1934.

10. Exploring the World of Science, Charles H. Lake, Henry P. Harley, and Louis E. Welton, Silver, Burdett and Company, Boston, 1934.

11. A Learning Guide in General Science, Philip Boyer, Arthur S. Clark, Hans C. Gordon, and John Shilling, Lyons and Carnahan, Boston, 1935.

In addition to the above source of data, on February 1, 1936, a letter was mailed to all high-school principals in the state of Massachusetts asking them to place in the hands of interested and qualified teachers an inquiry concerning the kinds of home-made apparatus being used in their science instruction, and its effectiveness. Replies came from teachers of general science, biology, chemistry, and physics, and from teachers in schools having a variety of enrollments. It undoubtedly includes, in addition to a certain percentage of original procedures, a large number of suggestions which were

taken by the teachers from the text in use. The letters from teachers who reported the use of certain of the textbook suggestions are especially valuable in that they indicate those activities proposed in the book which have found actual use, even though they are not original with the teachers reporting them.

Beyond these sources, a few extracts were made from The Science Masters' Book.

C. Presentation by principles.

In any method of organization subjective opinion must provide the guiding foundation. In analyzing the texts it was found that the experimental demonstrations were arranged under the heading of topics and generalizations relating to topics. One of the inconsistencies which became apparent as the number of texts analyzed increased, was the diversity with which different authors found it possible to work into their texts the different experiments. For example, the matter of explaining the presence and amount of water vapor in the air in the different texts was placed under five different topics. Thus, in the topic "water" it occurred under the idea of the three physical states of matter; in the topic "air" under composition; in the topic "weather and climate" under the heading rainfall; in the topic "heat" under the principle of the energy manifestations concerned with the change of state of a material, that is, with vaporization and condensation; and in the topic "our bodies" under the study of the relations

of the health of the body and the composition of the air. Or again, the same topic occurred in the chapter "weather and climate" in explaining the convection forces due to the resultant change in the specific gravity of the air to which water vapor has been added. To cite another example: The explanation of the construction and operation of the mercurial thermometer occurs (1) in the topic "weather" and (2) in the topic "air" in connection with the discussion of fluid-volume changes due to temperature change; (3) in the topic "ventilation", and (4) in the topic "our body" in discussions connected with relative humidity. Because of these many inconsistencies and disagreements apparent in a tropical organization, this thesis material is classified under the principles involved. This seems in line with the modern thought concerning the organization of courses. Since principles are basic to comprehension, or again, since the purpose of general science is to introduce the student to the principles underlying his environment, it would seem more practical to group it in the form of topics.

D. Concerning "originality."

In this thesis no attempt has been made to determine the "originality" of suggested procedures. Some of the experimental procedures included in this paper were found in as many as seven texts. It would be extremely hazardous to attempt to determine originality in such cases. Many of these experi-

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ments are the result of heritage from one generation to another. Excellent procedures are lost in this manner. The most successful way of demonstrating osmosis known to the writer was contained in none of the sources examined, yet was observed in a high-school biology class twelve years ago. It is interesting to note, further, the comment in the preface of The Science Masters' Book:

> "A great many notes are original, or believed to be original, though it is sometimes difficult, particularly in Natural Science, to be quite sure on that point. Many, however, whose names are put to the notes, emphatically disclaim original authorship. The ideas have been acquired from forgotten sources and no doubt many old ways of doing things have been brought up again."

Because of this uncertainty no attempt is made to connect the originator and his ideas.

CHAPTER II

ENERGY MAY BE TRANSFERRED FROM ONE PLACE TO ANOTHER AND CHANGED FROM ONE FORM TO ANOTHER

A Flow of Electrons Excites a Magnetic Field.

The combinations of material in this field are varied in design and almost limitless in number. Set ups and procedures which illustrate the extent to which improvised apparatus may be used to develop this idea, are:

A. <u>Detecting a current in a wire.</u>

1. Dip a length of copper wire, connected to a dry cell, into a pile of iron filings. Notice the effect of current in the wire by breaking the circuit after the wire and its load have been lifted into the air.

2. A wire is placed parallel to and under a compass needle. As the current is turned on the needle is deflected and as the current is reversed the needle is found to swing the other way. Carry the current-bearing wire around, under, and over the indicating needle and notice that the magnetic field of the wire in most of the many positions, causes a deflection of the compass needle.

3. A concentric ring pattern of iron filings can be secured by the passage of a comparatively weak current through a single wire strand, as shown in Figure 1. Tapping the cardboard disturbs the rest of the iron filings which stop in a position conforming to the force of the magnetic lines of the wire carrying the current.

These ideas are used as a means of testing for the presence of a current in a wire.

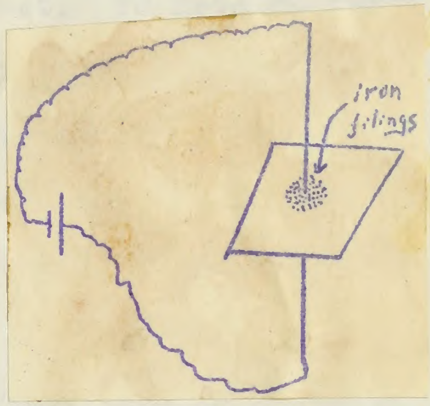

Figure 1. Tracing the magnetic field.

Use the 60-cycle, 110-volt current in the preceding experiments. For example, attempt to trace the magnetic field with the cardboard and iron filings. As an indicator of the flowing of the current hook a light bulb in series. It is curious to find that although the wire carries current, it shows no field because the magnetic effects are self neutralizing due to the alternating character of the current.

B. <u>Making temporary and permanent magnets</u>.

1. Wind an unmagnetized nail with fine insulated copper wire. A current passing through the wire causes the nail to act like a magnet. This is illustrated if the wound core is dipped into a pile of paper clips, pen points, thumb tacks or iron filings. The magnetism induced in the nail is

indicated as temporary by cutting the circuit while these bits of iron are held in the air. A nail, spike, horseshoe, or pieces of tin are suitable as the core for the wire.

2. The strength of temporary magnetism depends upon three factors: core, coil, and current. To develop these ideas respectively: (1) Use cores of glass and iron of like size. (2) Use a single turn and 10 turns on two like nails. (3) Use one cell and three cells as the current source of like electromagnets. In each case, test the lifting powers for comparisons as shown in Figure 2.

3. The idea of permanent magnetism is developed by using steel cores for the electromagnet. Scissors, a hammerhead, knitting needles, a file, a knife or a screw driver are pieces of steel that bring results. Again, the set up shown in Figure 2 is a convenient means of comparing the qualities of different types of material around which to twist the wire. The strength of two equal-sized needles will be nearly the same, although one remains in the magnetic field for a few seconds and the other a few minutes. Wind a mailing tube with many turns of wire. Insert pieces

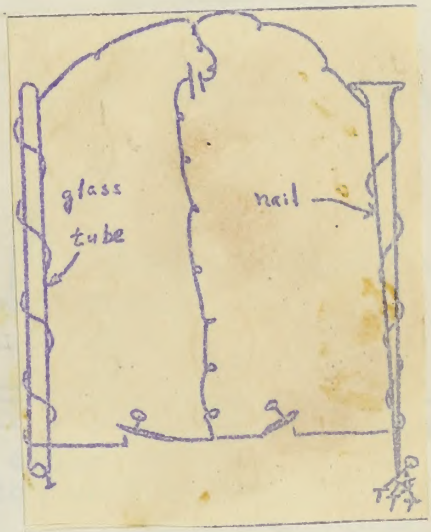

Figure 2. Simple glass-core and iron-core electromagnets.

of steel into the tube. These materials become permanent magnets if current is sent through the coil.

C. Telegraph apparatus.

In the procedures just described the force of electromagnetism holds to certain materials. To develop the idea that electromagnetism, in addition, can cause materials to move use the simple telegraph sounders and sets below:

1. Nail a tin striker to a block of wood as shown in Figure 3. To intensify the sound of the clicks of the movements of the striker, attach to its free end a headed rivet, a screw, or a short bolt and nut. Also, equip the striker with an elastic band to cause its rebound against a ring of the ring stand.

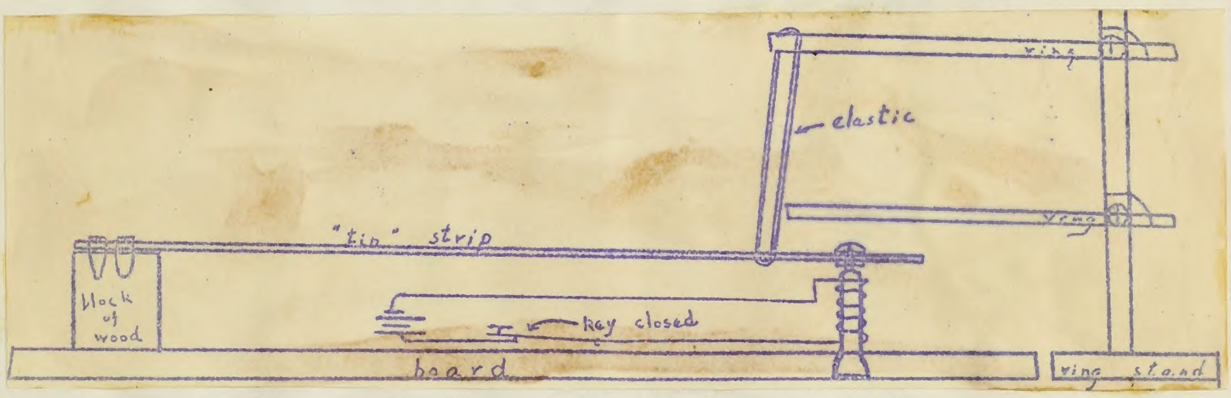

Figure 3. Elastic band to cause the rebound of the armature of the electromagnet.

An armature provides its own rebound if it is bent into a "U" shape and mounted on a board as shown in Figure 4. A door hinge, as the armature, uses the force of gravity to cause the recovery motion. See Figure 8.

2. An iron plate held in the hand above the end of an electromagnet will enable the holder to feel the pull upon the plate. This is shown in Figure 5.

Figure 4. A simple electromagnet as a telegraph sounder.

3. By making the electromagnet stronger, and by constructing a key, the device may be used either as a sending or receiving set. In Figure 6, (1) the "tin" armature is cut in the form of a "T" the small end of which is tacked to a block of wood; (2) two nails are set up as the electromagnet; (3) a piece of tin as the key is fastened at one end to the supporting baseboard.. The wiring of the two nails is done in such a manner that the direct current will, when it flows, circle each of the nails, respectively, in the opposite direction.. A piece of soft iron (not shown in the Figure) connects the bases to make of them a horseshoe electromagnet.. The free end of the key when pushed down completes the circuit and thereby is the sending key. If it remains clamped down under the edge of the contact point, the outfit automatically may be used as a re-

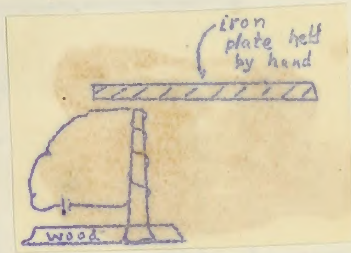

Figure 5. The force of electromagnetism.

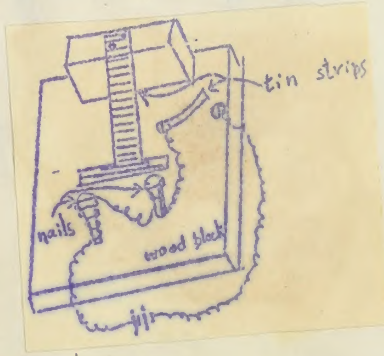

Figure 6. A home-made telegraph sender and receiver.

ceiving set. Now, by hooking together two or more of these sets individuals may intercommunicate. The amount of wire at hand determines the distance by which the individuals may be separated from each other. However, the sets may be grounded through water pipes as a means of eliminating one of the wires.

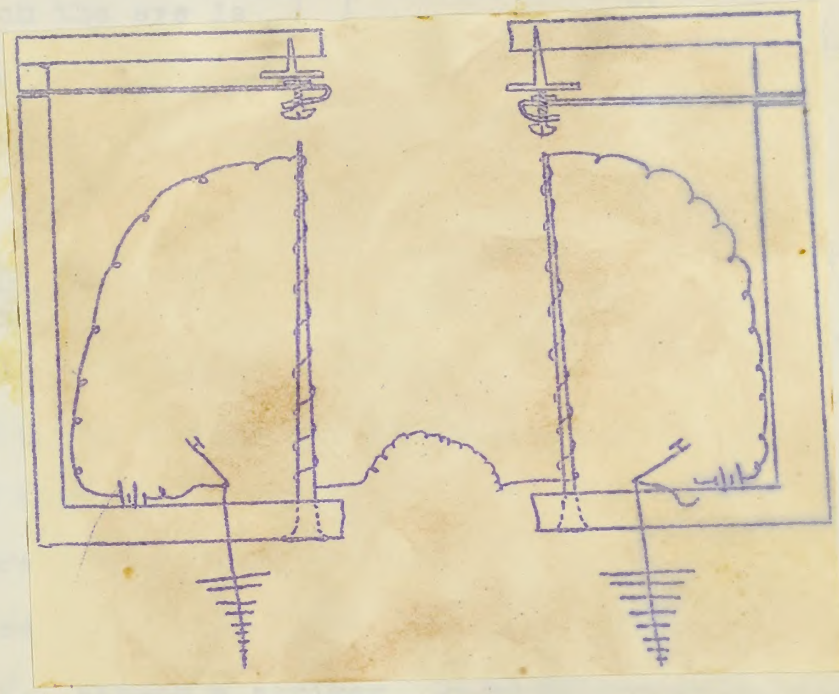

Figure 7. Another two-way telegraph set.

Figure 7 shows a second apparatus to use between rooms in the school, or at home. The ⏚ symbol means water pipes or steam or hot water radiators which are grounded. If the "ground" has corroded, file, sandpaper, or scrape the metal until the places at which contact is to be made are shiny.

In these experiments the armatures and sending keys are provided by the magnetic metal of the common food cans. This material is iron with a thin coat of zinc or tin. It can be

cut and flattened and thereby fashioned into the needed shape. In Figure 8, an iron hinge is used as the gravity-controlled armature and a clothes pin of the spring type as the key. A sending and receiving key is provided by a hook and eye in which the eye is the key-contact point and the hook the sending button.

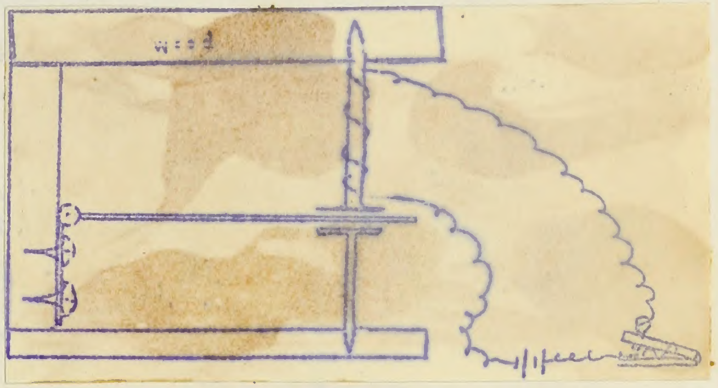

Figure 8. A door hinge and clothes pin as armature and key, respectively.

D. The electromagnet as buzzer and bell.

1. The use of the buzzer opens the way for the understanding of the circuit breaker of the electric bell. Figure 9 presents an easily constructed design.

2. Attach a striker to the armature of the buzzer and an electric bell results, since the two are the same mechanically. To develop the understandings of the operation of a bell for a large group, use a yard -or meter-stick or a lathe as a huge armature. Armatures of unmagnetic substances, however, must carry iron plate to respond to the magnetic field. Any plates can be fastened to the armature in one of many ways. It is suggested

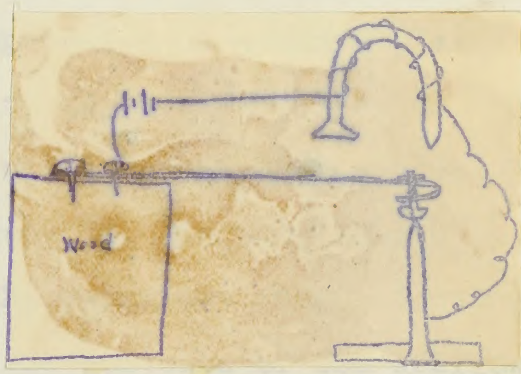

Figure 9. To show an armature circuit-breaker.

in the case of very crude set ups that the use of the actual electric bell follow work with the over-grown improvised apparatus. Three cells, in Figure 10, may be necessary with the larger armature load.

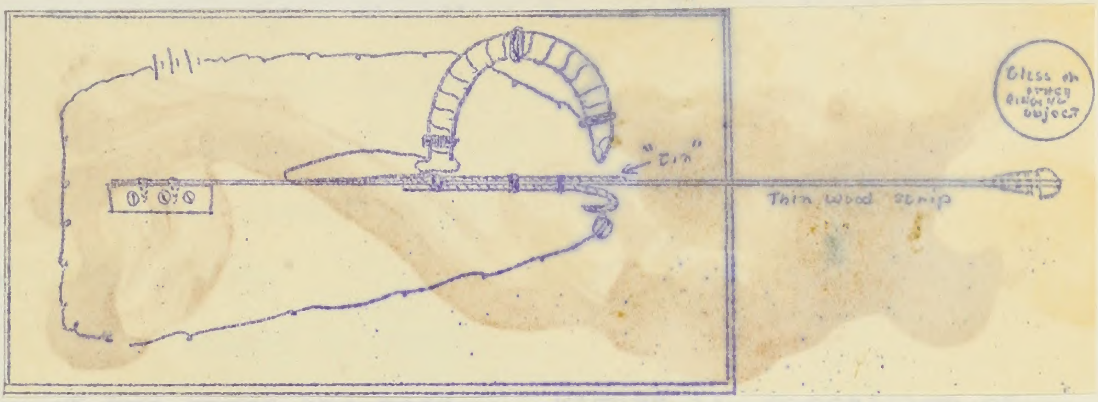

Figure 10. To see the electric bell parts in operation.

E. <u>The</u> <u>galvanometer</u> <u>and</u> <u>the</u> <u>electric</u> <u>motor</u>:

The electric motor may be constructed in several ways with improvised equipment. This apparatus develops the idea that the motion of the wire carrying the current is an adjustment to the magnetic field in which the wire is placed.

1. Notice carefully Figure 11. In this case a strong horseshoe magnet provides the permanent field, and the dangling wire, "A", when touching the contents of the shallow dish filled with mercury, carries a current. However, the current establishes a magnetic field which weakens the field of the permanent magnet on one side of the wire, and which strengthens the field of the permanent magnet on the other side. The wire therefore swings away from the opposition to one side. In this way the current is broken as the wire swings

out of the mercury, the swinging force is lost, and the wire returns to again complete the circuit and to repeat this action. The wire resembles a pendulum going through but half of its motion. Reversing the direction of the current in the dangling wire causes the "pendulum" to adjust itself in the opposite direction.

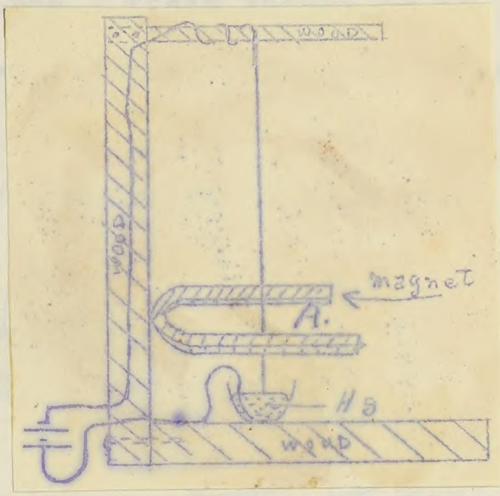

Figure 11. Opposition of magnetic fields resulting in motion.

2. Simple galvanometers of two types are readily developed as illustrated in Figures 12a and 12b. Necessary to this work are: source of current, length of insulated wire, and a magnetic field,

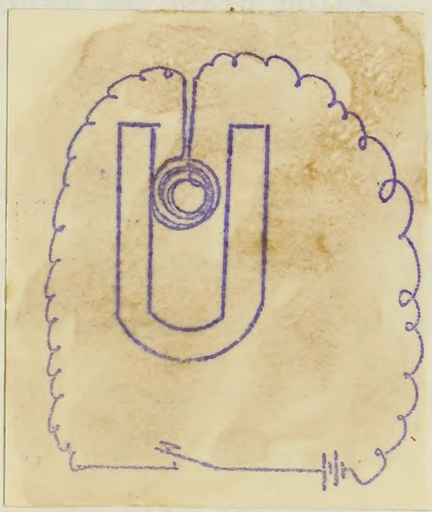

Figure 12a

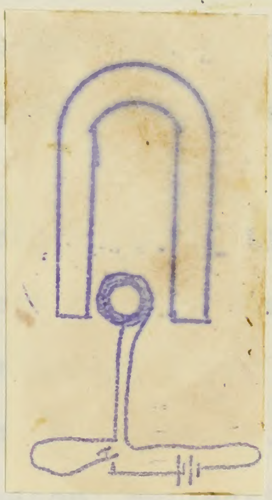

Figure 12b

The movable magnetic field self-adjusting to the fixed field.

well provided for by a horseshoe magnet like that of an old

automobile generator, or of an old country-telephone box. The coil works better if its field is intensified by winding the coil around some pieces of soft iron. These should be no longer than one inch to allow free rotation within or between the poles of the horseshoe.

3. Three principles are important to the understanding of the action of an electric motor. These are: (1) An electromagnet, like a permanent magnet, has two poles. (2) The location of these two poles depends upon the direction of the current through the coil. (3) Like and unlike magnetic poles, respectively, repel and attract each other. Figure 13 represents one of the methods of putting together a home-made electric motor.

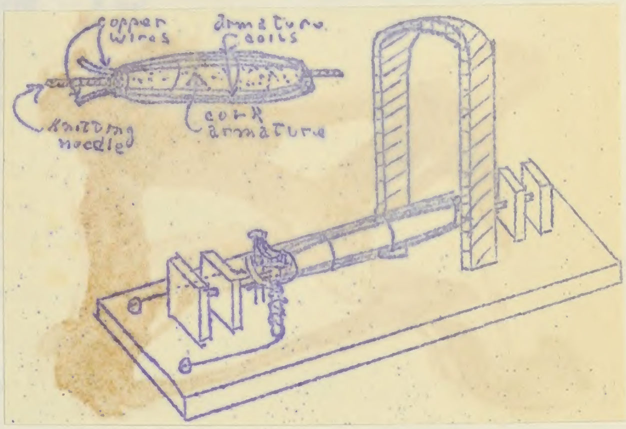

Figure 13. Two nails as motor commutators.

4. A second home-made electric motor is illustrated in Figure 14. Four nails, 40 feet of fine insulated copper wire, a piece of board, a cork stopper, a dry cell, and "tin" foil complete the list of needed materials. Perhaps, again, (in the mind of the originator) reflection upon the ease with which a compass needle can be whirled by a magnet in an operator's hand may have been the idea leading

to this spinning device. The home-made compass with the magnetized steel of the watch spring, or safety razor blade, supported on the glass tube and sunk in the cork stopper, of Figure 15, is a third arrangement of materials for the motor.

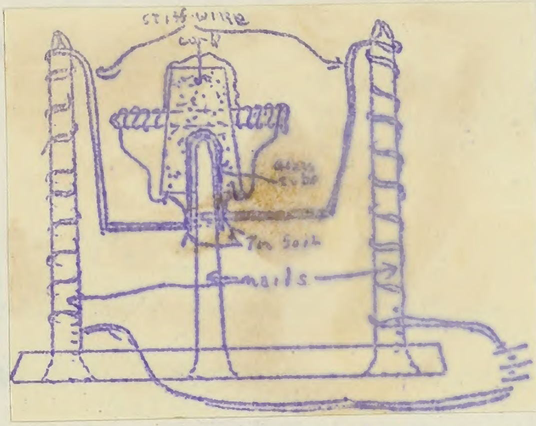

Figure 14. A piece of rounded glass tubing, sunk in cork, as a rotor on a nail point.

5. At many five-and-ten-cent stores, a set of simple parts for the toy motor model can be obtained.

6. Likewise, copper wire, bar magnets, two dry cells, a piece of wood, and thumb tacks, as indicated in Figure 16 are easily assembled. Mount the supports on the wooden base with the tacks, and connect the tacks to the dry cells.

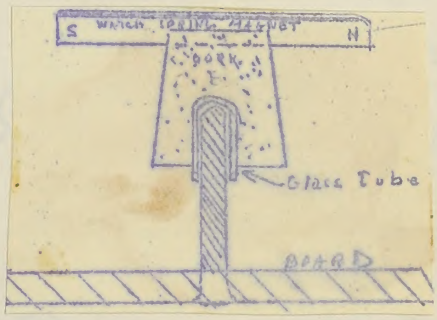

Figure 15. Another magnetized rotor.

The armature has its twisted ends carefully wound, as shown, and resting in the cups of the copper supports. In the sketch, one side of the twisted ends of the armature is on top, while

at the other side, it is at the bottom. The bar magnets are placed so that opposite poles face each other, with the armature in between. The armature, if turned, should continue to rotate.

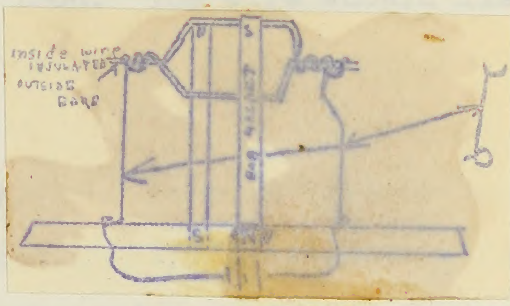

Figure 16. Bar magnets, wire, and thumb tacks as a motor.

Either a Magnetic Field Changing Near a Wire
or Motion of a Wire in a Magnetic Field
Produces a Flow of Electrons.

To comprehend the following experiments the pupil must know that a flow of electrons, an electric current, may be indicated by a galvanometer or a compass. Home-made compasses having a considerable of sensitivity may easily be constructed.

1. The most sensitive device is needed to perform the first experiment. As shown in Figure 17 it consists in moving a wire, held in the hands, in and out of the horseshoe magnet. A less sensitive compass may be used if the wire moved is attached to a coil of many turns of fine insulated wire wound

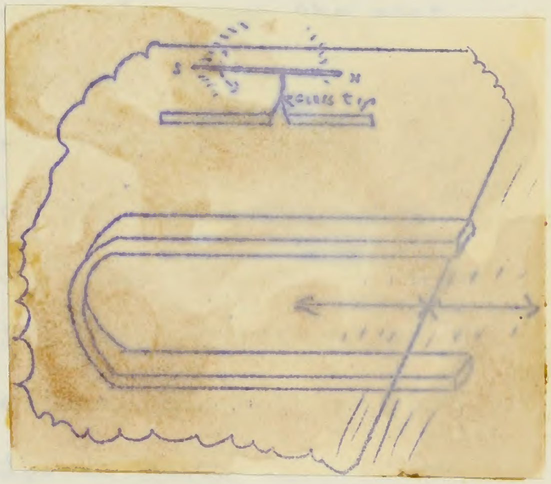

Figure 17. Compass as a galvanometer.

about the end of a piece of soft iron. The wire should lie in a horizontal plane as near as possible to the side of the compass needle.

2. Move a coil of many turns of wire through the magnetic field of a permanent magnet. If a horseshoe magnet produces the field, the motion is in and out of the space between the poles. However, if bar magnets provide the field, slide the coil up and down as it surrounds one of the bars.

Observations of the current indicator are useful for the following types of motion: (1) The coil moves in each of two directions through the field. (2) The field moves in each of two directions near the coil. (3) The field and coil halt. (4) The speed of motion of the coil is varied.

In all cases the current indicator must be at such a distance from the magnetic field as to be beyond its influence.

3. By careful and time-consuming work the most satisfactory result is obtained by hooking up the most stable of the water-wheel models with a generator or a motor having a permanent field. The two wires of the motor are led to the tiny electric-light bulb of a small flashlight, as shown in Figure 18. A speedy water wheel will convert its energy of motion in sufficient electricity to cause the bulb to glow. This is especially true in localities in which the water-main pressure is enough to make the toy water wheel operate at a fast rate of speed.

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To make the water wheel the following are needed: a rigid flat box, like a cigar box, one foot in its lesser dimension; metallic strips an inch wider than the board is thick; a board about an inch thick; a bolt, nut, and washers; a spool; and a strong fine wire. Cut the board into a regular octagonal shape the dimension of which is two inches less than the smaller dimension of the box. The water buckets are made from the metal stripping as described below and as seen in the illustration.

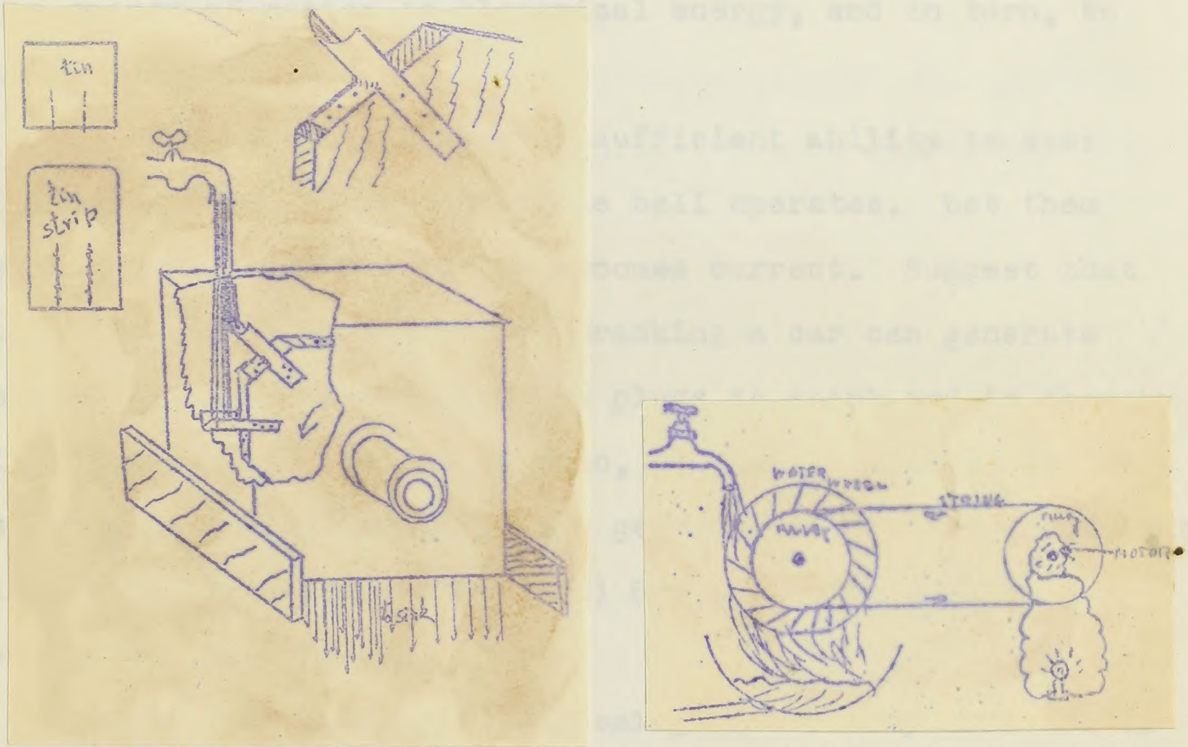


Figure 18. A water wheel generating electricity.

The stripping is cut into 8 three-inch lengths, each of which is bent into halves. A cut is made along the crease from each side leaving an uncut central portion the width of which is

the same as that of the board. The uncut portion can be bent to form the water cup after the edges are turned back to form the attachment border. Then a bolt, which is put through the spool, becomes the axle upon which the water wheel is to be mounted in the box. The string is the connecting link between the motor and the water wheel. A hole is cut in one side of the box to allow the entrance of the water, and the opposite side is opened to act as the spillway. Placing this over the sink provides a location adapted for the operation of changing the energy of motion to electrical energy, and in turn, to light energy.

4. Some pupils have sufficient ability to see: (1) How an old country-telephone bell operates. Let them examine one. (2) How motion becomes current. Suggest that they think of a person who by cranking a car can generate enough electricity to cause the plugs to spark and to thereby ignite the gas. (3) How an auto, lacking a battery, if once started to moving downhill, may generate electricity to operate lights and ignition system, (4) How the autos used to be started by the magneto.

Of course, mere motion becoming electricity does not explain change in voltage, but in the following are some activities which have as one purpose that of helping to develop this principle.

A Current of Electricity Has a Magnetic Field, but the Field Tends to Induce a Current Opposing the Original Flow of Electricity.

1. Wind a spike with many turns of number 28 insulated copper. Hold in the hands the bared ends of the wires which have been attached to three dry cells in series. Allow the current to pass through the coil and suddenly break the circuit. A significant shock is felt to pass through the body. It is of strength (voltage) greater than that of the battery cells alone. The magnetic field of the original current builds up such opposition that when the current stops, the unopposed magnetic field induces its own current of considerable voltage.

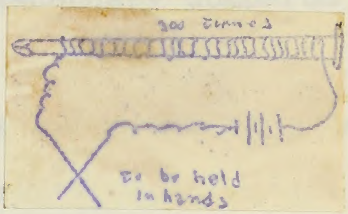


Figure 19. The spark of self-induction.

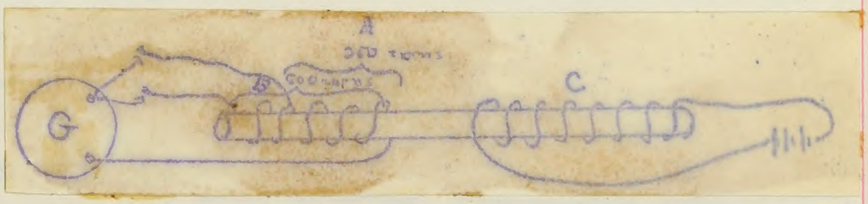


Figure 20. A transformer.

2. Wind one-half of the length of a soft iron bar with 500 turns of number 28 insulated copper. Wind the other half with two series of turns, 250 each, of the same type of wire. Hook the first 500 turns to a battery of two dry cells. A galvanometer is used to detect the flow of current through the windings on the second half of the bar, as shown in Figure 20. While passing the current through the 500 turns, have

one-half of the other turns attached to the galvanometer. Then repeat the process with both coils of 250 turns in the secondary circuit. In each case a deflection of the galvanometer needle occurs. The degree of deflection is dependent, apparently, upon the number of turns of wire of the secondary compared to the number in the primary.

3. Use the 110-volt, alternating current to show the weakening effect which a current by self-induction has upon its strength. In Figure 21, either circuit "A" or circuit "B" illustrates. In each case a lamp is used as an indicator of the strength of the current. In the first case it is hooked in series with a many-turn coil of fine insulated copper wire. When a long piece of soft iron is thrust slowly

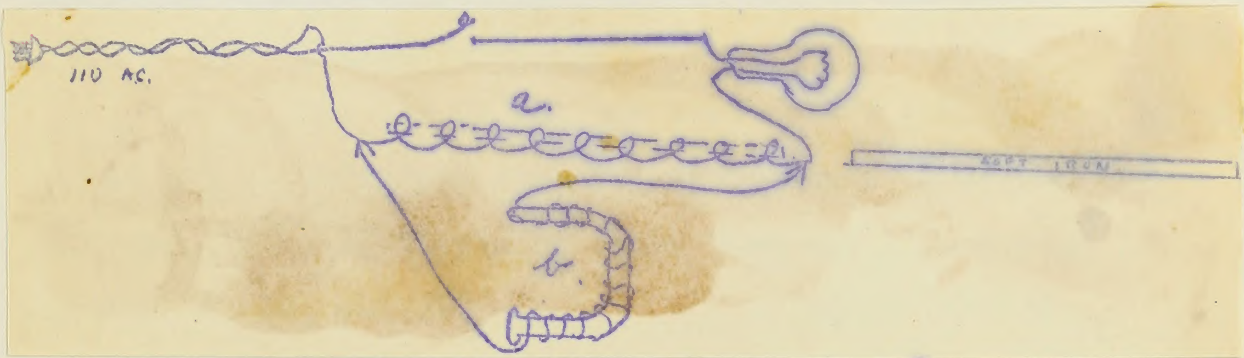


Figure 21. The magnetic field induced opposes the flow of electrons.

into the coil which is carrying the current the light becomes dim, and as the current is shut off, the lamp is observed to become brighter. In the second use the light hooked in series with the "horseshoe" electromagnet assumes a certain brightness

and surprisingly, when the circuit is broken the light momentarily becomes brighter.

In each case, the increased intensity of the light bulb as the alternating current is switched off indicates the truth of the assertions that the alternating current induces a secondary current, and that this induced current tends to take a direction which opposes the original current.

The Pressure and Amount of Electricity Flowing May Be Changed by the Type of Hook-up, by Use of Self-induction, and by the Amount of Resistance Overcome.

A. Type of Hook-up.

1. The galvanometer's deflection is read for: each of several dry cells, all of the cells in parallel, and for all of the cells in series.

B. Use of self-induction.

1. The use of and the idea of the action of a transformer may be developed from the experiments concerned with self induction, particularly those that are illustrated in Figures 19, 20, and 21.

C. Amount of resistance overcome.

1. Figure 22 illustrates one ... developing the idea of the re- ...tween resistance and current. As the nail is rolled down the graphite rods the light dims; as the nail rolls back the light

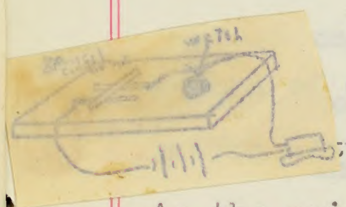


Figure 22. A graphite rheostat.

brightens.

Figure 23 shows a result similar to that noted immediately above. Observe the intensity of the sound of an electric bell as the metallic sheet "A" is moved successively, over the series of contacts. These points are thumb tacks in between which are different lengths of wire of various materials. The bell may be improvised as shown in Figure 10 if necessary. It will be more effective if the small manufactured bell is used here.

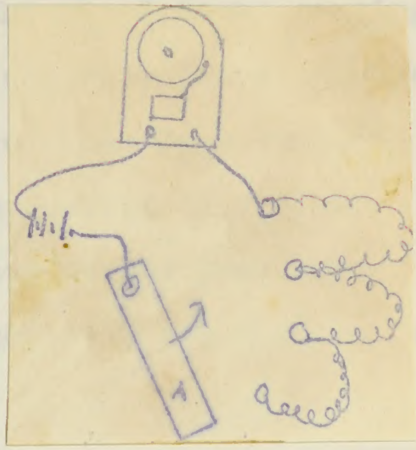


Figure 23. A wire rheostat.

2. Telephone mouthpieces, in fact, all microphones, regulate the flow of electricity coursing through the circuit. The principle of the telephone transmitter may be developed as (1) the pencil carbons, shown in Figure 24, are scraped together, (2) the ticking watch of Figure 25 or some other simple vibration causes a variable current to flow through the carbon parts of the circuits. Use of a cigar box for the wooden support of Figures 25 and 26 allow use of a trapped buzzing insect as the source of the sound-wave vibrations. Apparently, in any case, this is possible

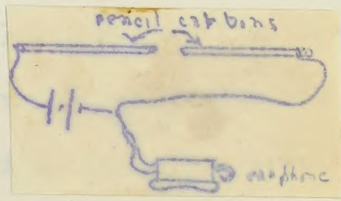
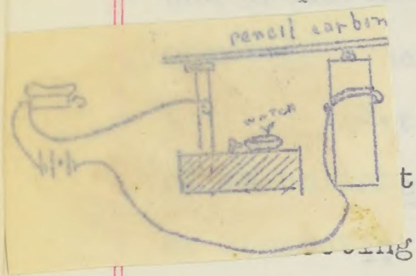


Figure 24. Microphone from pencil-leads.

Figure 25. Microphone for watch vibrations.

only for the reason that the force of the sound waves causing the carbon particles to be alternately compressed and released, results in a variable resistance, and resultantly a varied current. Particularly, this appears to be true in the case of Figure 24, in which case, more intense sounds come from the earphone as the pressure of the hands with the carbons is



Yet another arrangement
tening nature is assembled
ing one pole of a dry cell
to either post of the headphone and the other to a coarse file. The second post of the receiver is attached to a long wire, the free end bared of insulation is to be scraped over the length of the file. The use of a finer file has a significant effect upon the sound produced at the earphone.

Figure 26. Microphone for a "ticker" or buzzing insect.

4. Figure 27 illustrates the principle that the quantity of electricity passed depends upon the amount of resistance. The vibrations of an alarm clock "tick" are well transmitted by particles of carbon and a piece of copper resting on the back of the clock.

Figure 27. Microphone of carbon particles.

A Flow of Electrons Causes Chemical Action
and Chemical Change Is the Cause
of a Flow of Electrons.

The industrial applications of this principle are endless in variety. Electrolysis, electroplating, the production of certain materials, storage of the energy of water power, and production of the forms of energy are the topics concerned. The development of this principle can lead the far-seeing pupil a great way in the field of general science.

A. Electrolysis suggestions.

1. In developing this principle for a large group of people, the usual methods for the electrolyses are too slow, and are such as to be visible to only the few nearest to the apparatus. The equipment used as shown in Figure 28 solves these problems. The gas collecting tubes are shipment length, five feet long, and eight to ten millimeters in diameter. They are mounted vertically on a lecture table parallel to each other. Electrodes of platinum are of one of the combinations possible to improvise at home. They are inserted into the lower end of each tube and the whole is lowered into the jar of water, slightly acidulated with sulphuric acid.

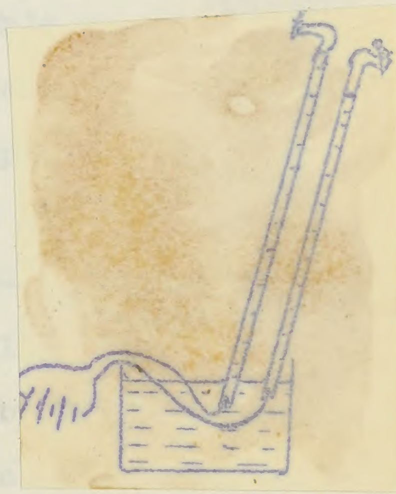


Figure 28. Speed in electrolysis.

The top of each jar has a hose attached and is equipped with a stop-cock. The tubes are sucked full of water and are quickly clamped to hold up the water. The action is immediately started by closing the circuit. The composition of water may be indicated first, as to the quantities of its component parts, and, second, as to the probable chemical nature of each part. Action seems fast because the tubes are of small diameter; it is within the sight range of all because of the height of the tubes.

2. An apparatus of the more common type is seen in Figure 29. This is a piece that may well become permanent for electrolyses of a simple nature. It surpasses the usual unstable improvised style, and seems, in its homliness, to be clearer to the understanding, than the usual apparatus from the factory characterized by the fine finish of the projecting graduated jet tubes and by the shiny metallic binding posts. Prepare the container by cutting clean the bottom of a gallon bottle. To do this tie an alcohol saturated piece of string around the bottle at the desired place of fracture. Burn off the alcohol in the string and saturate it again with a brush soaked in alcohol. Repeat this several times and then place the bottle under the cold water tap to complete the fracture. Another way to heat the flask or jar

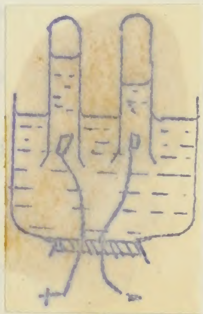


Figure 29. A permanent electrolysis jar.

along the plane of the desired place of fracture is to use a flame. To do this well, set the jar on the edge of a table so that the end, which is to come off, protrudes. Regulate the length of the jar extending out from the bench by pushing the other end against a flat resistance which in some way is firmly fixed to the table. Set the flame to be used directly under the line of heating and slowly rotate the jar until the glass over the flame is thoroughly and evenly heated. When this condition has been reached, set the jar into a shallow dish containing sufficient water to just reach the heated region of the jar. For safety in the repeated use of the jar, it is wise to smooth off the freshly-cut edges with a flame melting the edges smooth, or by use of a fine sandpaper, number "00", double zero, soaked in water. The test tubes are held in place by clamps, or to get greater visibility, and apparent speed, the set up of Figure 28 is used. Copper wires can be used more efficiently, if waxed, except at the ends.

Concerning electrolyses in general there are several notes important in considering the varieties of equipment possible: (1) Platinum electrodes are best, and are relatively inexpensive if the permanence and inactivity of the material is considered. Long platinum wires are unnecessary; only the wires leading through the solution from the stopper of Figure 29 need be of this expensive metal. (2) Unsatisfactory

electrode combinations are those of copper in solution ionized by sodium hydroxide,(although lead is satisfactory in this hydroxide) and of lead in sulphuric acid. (3) Copper and tin are satisfactory as electrodes in sulphuric, hydrochloric acid, or salt.

3. The electrolysis of hydrochloric acid is interesting and simple. Use carbon electrodes, and a salt solution of strong concentration. The salt is changed to chlorine and sodium, but the sodium reacts with the water to liberate hydrogen and form sodium hydroxide. Hence, both hydrogen and chlorine can be easily prepared in this way for observations.

In all electrolyses the problem of current is important. A direct current is essential, and is obtained from dry cells, or storage battery in useful quantities and strength. If the 110-volt alternating current is the only available source, it is unsatisfactory for electrolysis for two reasons. First, it must be changed to direct current, or have one phase of its alternating character eliminated, and second, it must be weakened. In Figure 30 the electric light bulb effects the weakening of the current, (also making a convenient switch) and the cell of borax or soda solution, sodium carbonate, will only carry electricity from the lead to the aluminium. It is particularly important to note that a layer of lubrication oil is necessary to prevent these materials from burning very

quickly. Keep the solution covered with a layer of such oil to the depth of half an inch. The solution is a concentrated solution. Electrolysis apparatus for common analyses is supplied with a satisfactory direct current if hooked into series with the resistance and rectifier of Figure 30.

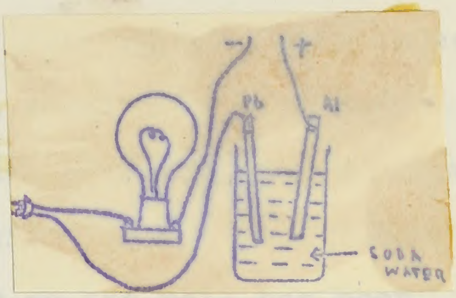


Figure 30. Rectifier and resistance for electrolytic use of 110-volt alternating current.

B. Industrially important electroplating.

1. A dime may be made into a penny-like coin if it is placed in a solution of a copper salt and electroplated as follows: Connect the silver coin to the negative and a copper strip to the positive of a direct current. Immerse the two plates into the solution so that they are not touching each other. Any combination of metals may be used in the solution of the salt of the metal doing the electroplating. As above, always fasten the plating metal and the metal to be plated to the positive and negative poles, respectively. In this particular case, the result in terms of coating one metal with another is observable after thoroughly drying and then buffing the blackened dime. This treatment develops the gleam of copper particles and a bronzed appearance. Likewise, a piece of the graphite from a pencil, a teaspoon, a knife blade, or a wire nail may be coated with copper. It is perhaps, best

to use the low-pressure, high amperage hook-up of the parallel type from four cells.

With several metal combinations no electrical energy is necessary. The actual difference in chemical activity (see appendix, "Replacement Series") if great enough, will cause a more active metal, if immersed in a solution of a less active metal to become plated. Thus, after dipping an iron nail in a copper-salt solution, the nail will be found copper coated. Incidently, the copper now on the nail has been replaced by a small amount of the iron, now in solution. In this experiment in which the chemical action is apparent, there was a hidden flow of electrons from the iron to the copper.

2. Use the electric current to make a simple storage cell. Two sheets of lead may be obtained from a lead pipe. Pound them to flatness. Waste pipe can be had at a plumber's. The lead strips are given a similar appearance by burnishing with a file, sandpaper, knife, or emery wheel to get the shiny metallic luster. Then, connect them to a direct current source, and immerse both into sulphuric acid diluted no more than one-to-eight with distilled or tap water.

As soon as the current begins to flow through this arrangement bubbles can be seen rising from the electrodes, and the color of them appears to change. Stop the current by taking out the lead poles for a moment and observe that there

is a definite change in appearance. Then, connect up the apparatus with the current so that it goes through the solution in the direction opposite to that of the first trial. Observe that the changes are now occurring in reverse order, that is, that the plate becoming discolored now is the one which before seemed little changed. Keep the electrodes immersed for 15 minutes without allowing them to come in contact with each other. Then, disconnect the source of direct current and quickly hook up the newly-made storage cell with wires leading to an electric bell. The simple apparatus, in causing the bell to ring, has apparently stored up the electrical energy of the direct current. The change in the appearance of the electrodes and the liberation of gaseous bubbles during the "charging" process indicated that the electrical energy used for charging the cell caused a change in the composition of the plates.

The process of discharging the cell, if this is done, is the opposite of the charging process--the chemical action of the solution upon the two plates, which after charging are of different materials, is changed to the electrical energy for ringing the bell.

C. <u>Chemical action may cause a flow of electrons</u>.

That is to say, "chemical energy may be converted to electrical energy." The principle is basic to all types of batteries in which electrical energy is released when the

ingredients of the battery are conditioned to react with each other.

1. The simplest cell is the traditional voltaic the materials for which are common. Burnish zinc and copper strips over the areas to be immersed and at the place where the connecting wires are to be attached. Welding is preferred in making the attachment of the wire to the metallic strip. Paper clips will do, however. When the strips are in the acid solution chemical action is soon apparent, and if the wire joining the two unlike strips is tested it will be found to have a magnetic field. This indicates an electric current. The electrodes may be a combination of any two common metals except the copper-lead assembly. Tin, aluminum, zinc, and iron, will work with each other, or with copper. The particular metal which is the higher on the Replacement Series will prove to be the so-called negative pole.

A set of equipment of a more improvised type is: a strong salt solution as the conducting liquid, a jelly glass as the container, an old carbon and a zinc plate (from an old dry cell) as electrodes, wire as conductor, and a compass as galvanometer.

A set of equipment improvised from materials commonly found in the laboratory is: A quarter-pound of sal ammoniac (ammonium chloride) in a quart of water, a carbon rod, a zinc

plate, and a porous cup. Placed in the center of the cup is the carbon electrode which is surrounded by a paste of manganese dioxide, water, and graphite or powdered charcoal. The cup, in turn, is immersed into the sal-ammoniac solution until the liquid nearly runs in over the top of the cup. The zinc plate is set into the solution of sal ammoniac. The carbon and the zinc become the positive and negative poles, respectively.

Place two unlike electrodes into the pulp under the peel of a lemon. If the two poles are brought to a galvanometer or to the tongue a current will be indicated.

Instruct the group in the composition of a dry cell by examining a discard which has been opened longitudinally with a hack saw. To show that moisture in a dry cell is necessary to provide for the transmission of electrons, punch holes in the zinc can of several discards, and set them in a pail of water overnight. When a connection is made with an electric bell, most of the cells will again produce enough current to operate the bell.

A Flow of Electrons Liberates Electromagnetic Vibrations and Its Energy Is Partly Converted to Heat Energy.

A. Electromagnetic vibrations.

1. Begin here with the original experiment of Herz if there is available a spark coil capable of jumping

a one-inch gap. Figure 31 shows the terminals of the coil holding flat pieces of metal plate. A few feet away a wire loop which has its ends broken by a distance of about a quarter of an inch or less, is held. The operation of the spark coil causes a spark to jump between the terminals of the secondary loop.

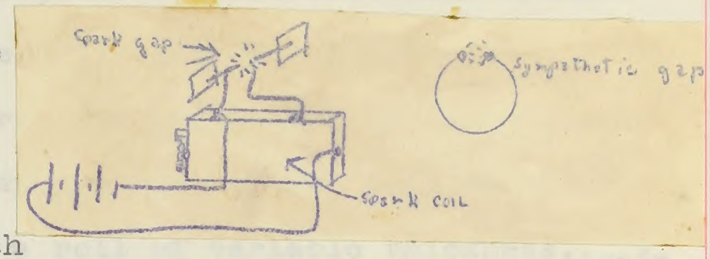


Figure 31. Use for a discarded auto coil.

2. Figure 32 is a contrivance which shows the same principle, that is, that a current liberates invisible, but nevertheless real, vibrations.

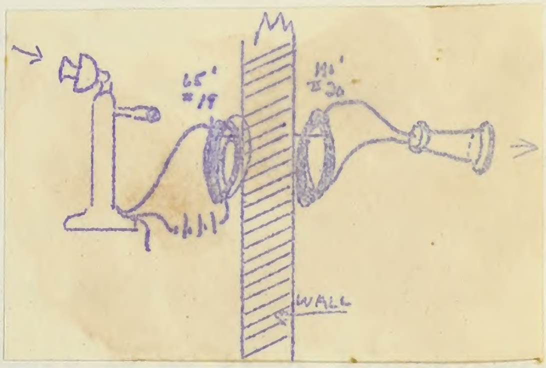


Figure 32. Electromagnetic vibrations.

B. <u>Electrical energy becoming heat energy</u>.

1. In Figure 33 is illustrated a hook-up which can be varied as many times as there are different conductors available. In addition, in this illustration there should be indicated a source of current. Resistances presented in turn should be studied to find the relation between the heating effect and the kind of materials

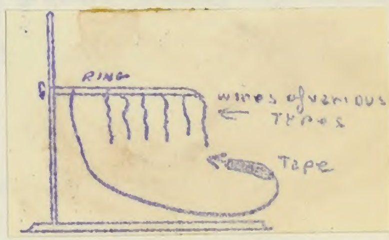


Figure 33. Heating effect of a current.

of the conductor, its length, and its crossectional area. Use the flat wire of an electric toaster, an old illuminating bulb, or the conducting wire of a radio coil or condenser. Metallic wires from gum wrappers may be made very thin and narrow or may be made into a roll of variable thickness. Again, the connections are best if soldered, but by clipping the connections to freshly scraped areas good contact is assured. The free end from the battery of cells has only its tip exposed while a coat of tape near the tip protects the hands of the experimenter from the heating effects.

2. Break a fuse and extract its wire. Hook this into series by a short length of copper wire to one or two dry cells. The melting of the fuse will show its purpose. With pincers lay a short fine wire across the poles of a dry cell. Feel of the wire if there is no other indication of the heating effect.

3. It is interesting (after ordering an ounce of bismuth metal) to make some low-melting point alloy by mixing it with tin and lead in the proportions by weight of five of bismuth, and two and a half respectively of each of the other two. This can be drawn into a slim filament which can be used as the conducting material.

4. A like result can be obtained by the following method: Melt three of the fuse wires into one mass and pour onto a smooth bench in one ball of alloy. With a flat metal

plate placed on the ball, it spreads into a thin sheet which may be cut into short suitable wires for heat testing.

5. An arc lamp is made using either dry cells or the domestic 110-volt current as the source. In each case pencil leads make satisfactory carbons. Take the strong current from a socket by the usual plug and cord. To each wire of the cord fasten several feet of fine copper wire. Fasten to the end of each of the fine wires a short carbon. Fasten tire or other insulating tape to the end of each of the fine wires to provide a place for holding each. Touch the carbons together. If a length of several feet of the fine wire is not available it will be necessary to protect the house circuit by substituting a number 30 fuse for the usual fuse of the circuit providing the current.

With the same small carbons, and a wooden box, four dry cells in series will furnish the energy required of a simple arc. The shell of a dry cell, that is, the zinc cover, is one suggestion as a glare cover for the carbons facing each other at right angles.

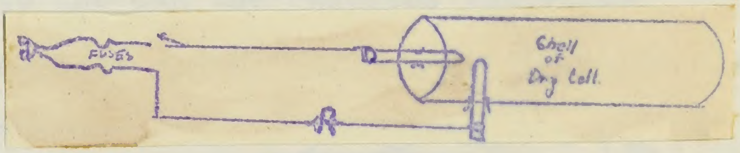


Figure 34. A dry-cell shell for a carbon arc.

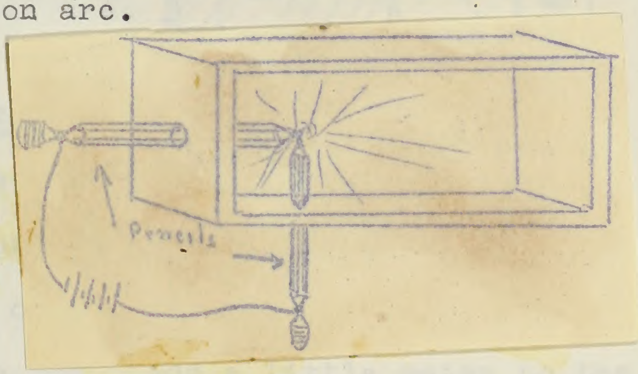


Figure 35. A wooden box shield for the intense light of a carbon arc.

Chemical Energy May Be Transformed into Motion of Particles of a Material.

A. <u>A spark starts action</u>.

1. To explode a mixture of gasoline vapor and air, use a second-hand magneto coil, a tin can with friction cover, and a discarded spark plug fitted into the side of the can. As a source of current hook three dry cells into series with the other apparatus as shown in Figure 36. Leave one of the wires of the secondary of the coil free so that by hand carrying it to the surface of the tin can, contact can be made to complete the circuit at will. Experiment with the amount of gasoline necessary by starting with two drops at first and by gradually increasing the deposit of gasoline until satisfactory results are obtained. If the bottom of the can is heated by a flame for a moment before the liquid gasoline is dropped into the can the gasoline vaporizes satisfactorily. The chemical energy adds sufficiently to the kinetic energy of the moving particles of the gas to blow off the friction cover.

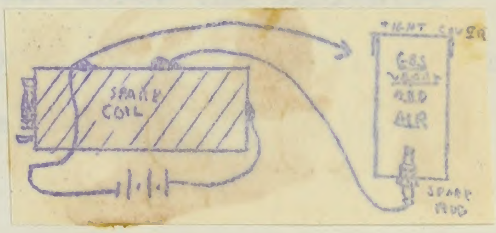


Figure 36. Electrically firing gasoline vapor.

B. <u>A flame starts action</u>.

1. Partly fill a tin coffee pot as shown in Figure 37 with illuminating gas. If this gas is not available, drop a few pieces of calcium carbide onto the bottom of the pot. Add a little water to the

carbide and immediately close the top to the pot. Then bring a wax taper, or a burning splinter, next to the hole at "a". This should result in an explosion, the amplitude of which depends upon the mixture of the gases.

Figure 37. To fire illuminating gas or acetylene.

2. In like manner, put some lycopodium powder into a friction-cover can, as shown in Figure 38. Through a hole in the bottom of a peanut-butter can, thrust the small end of a funnel. Cut a hole in the side of the can, as in "a" in Figure 37, and light a candle sticking to the bottom of the inside of the can. Place the cover firmly on top of the can, and after allowing the candle to burn for a moment, with a blast of air through the rubber tube force the explosive mixture of dust resting in the funnel top into the can. The mixture will probably be fired immediately by the candle flame.

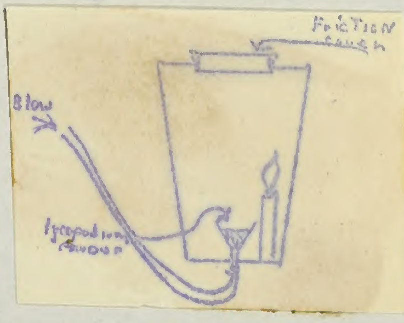


Figure 38. A dust explosion.

3. Cut a small hole in the side of any friction-cover tin can. Put a few small pieces of calcium carbide on the bottom of the can, and apply a little water to the bits of carbide. Jam the cover on tightly and bring a flame to the side of the can at the small opening.

As examples of friction-cover cans the following are a few suggestions: a paint can, Karo can, Crisco can, peanut butter can, coffee cans.

Frictional Resistance Is Lessened by the Substitution of Rolling for Sliding Contact, or by Smoothing Surfaces which Are in Contact.

A. Substituting rolling for sliding friction.

1. Use a spring balance to determine the weight of a book. Slide the book resting on its largest face over the surface of the bench and determine the force necessary to keep the book moving at a constant speed by dragging it at the end of a string attached to the spring balance from which readings are taken while it is in motion. Repeat two different ways. Place a round roller under the front edge of the book for the first reading, and place two rollers under opposite edges of the book for the second reading. Round pencils, pieces of chalk, knitting needles, finishing nails, or other similar objects make satisfactory rollers. Also, bits of glass tubing and thread spools are other suggestions for rollers.

B. Smoothing surfaces in contact.

1. With a spring balance find the effort necessary to drag a loaded box along the bench. Tack two strips of leather, smooth side down, to the underside of the box, and take another reading of the effort now necessary to move the load.

2. Make a measurement of the strength in terms of power of a water wheel or a toy motor by fastening the device to be measured to a simple "prony" brake as shown in Figure 39. The ends of a cotton string are tied together. The loop, thus formed, is fastened to the hook by a spring balance. The other side of the loop is then placed over the axle of the machine to be measured, and as the machine operates, the string is brought against the whirling axle with sufficient force as to just overcome the force of the machine. The reading of the spring balance measures the actual frictional force to overcome the active force. Two balances can be used by tying the ends of the cotton to the hooks of the springs. In this case, the average reading of the two scales measures the strength of the motor in overcoming the resistance of friction. If the number of revolutions per second of the toy machine can be computed, the strength of it in terms of horsepower may be computed. Measurement of sliding friction makes this possible.

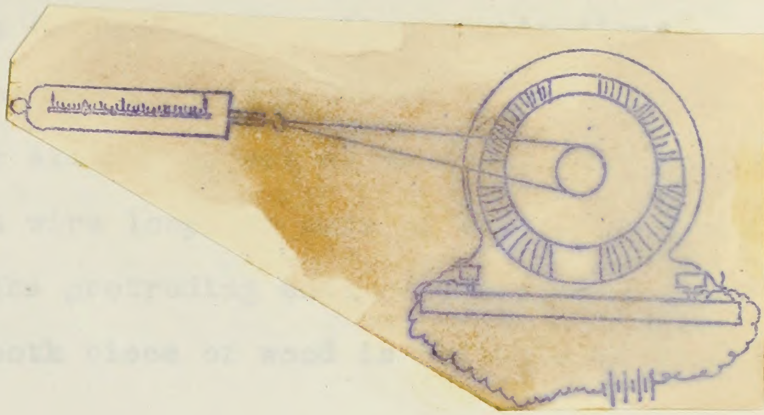


Figure 39. The "prony" brake.

Simple Machines Make Possible the Apparent Multiplication of Effort Applied, or of Distance through which the Resistance Is Moved.

1. Use pulley wheels from toy mechano or erector parts in various ways for different pulley combinations. Also, pulley wheels may be made from thread or wire spools rotating on a nail or similar object as an axis. The nail is easily supported by a wire loop the ends of which, in a semi-circle, extend over the protruding ends of the axle.

2. Any smooth piece of wood is suitable as an inclined plane.

3. The jackscrew of an automobile can find definite use.

4. As shown in Figure 40, a good application of the pulleys goes "home" as a girl or weak boy at "2", not only is found to be able to counterbalance the efforts of several of his stronger companions, at numbers "1", but also possibly to pull them in closer together than when they started. Clothesline and two smooth bars make the necessary equipment. The several opponents apply their combined efforts on the two bars.

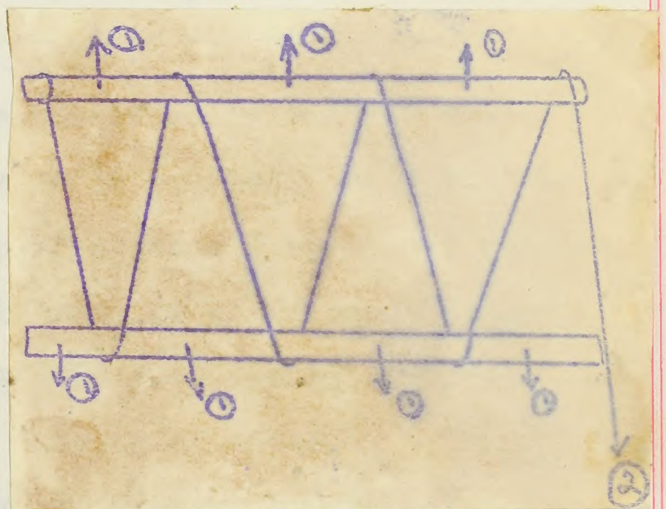


Figure 40. The pulley tug-of-war.

5. A model of the screw as an inclined plane is

made by wrapping a triangular piece of paper around the stub of a pencil.

6. Apparatus for the simple lever measurements may be made from a meter stick or other regular stick in which fine holes have been drilled at regular intervals. A nail to fit the holes will make a good fulcrum changeable for the demonstration of any class lever, and strings may be threaded through the holes and attached to the hook of spring balances by which measurements may be taken, or to weights as the loads.

The Force Produced upon an Object
by a Moving Fluid Depends upon
the Area of Object Exposed.

A. Moving water as the fluid.

Water wheels are as numerous in their variety as the materials from which they may be improvised. Satisfactory materials can be made from wood pieces and spools as rotors; waste metal and strips of thin wood or stiff paper as paddles; and nails or bolts as axles. Undershot, overshot, Pelton wheels, and turbines are easy to contrive.

1. An unusual model of a water or steam turbine follows: Drive a nail through a board with the nail sticking upward into the air. Melt the end of a glass tube which just fits over the end of the nail, and when the glass is soft, pull it out slightly into a point. Place one of the bits of tubing over the nail. Bore a small hole in the center of a

round board about a foot in diameter. Fit the board onto the glass tip. The board can now be fitted out with paddles on its upper side, and becomes a wheel that can be whirled either by the motion of water or of steam. With this axle it operates in a horizontal plane only.

B. Moving air as the fluid.

1. Take a pine shingle, four or five inches wide, and whittle it into an arrow shape. Use the thick end as the arrow head. Make the arrow neck about a half-inch wide. To find the balancing point, slide one finger along the underside of the neck of the arrow. Drive a small thin nail through at this point. The protruding sharp end of the nail penetrating the arrow is then driven into the round end of a stick like a broom handle. Spin the arrow around several times until it turns easily on its nail axle. If necessary tack marked lathes below the arrow as the compass pointers of the direction.

A Liquid and Its Gaseous State Differ from Each Other in the Amount of Motion of Their Particles.

1. Heat the tube carrying the cork stopper as in Figure 41. The particles of water vapor will become sufficiently active to blow off the stopper.

2. The apparatus of Figure 42 shows that once the fast moving particles again slow down, the condensed substance seems the same chemically as before. The lamp

chimney furnishes the shell for the cork plunger. This ex-

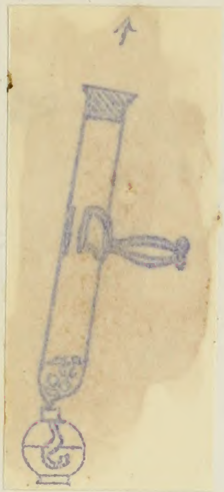


Figure 41. Particles of gas and pressure.

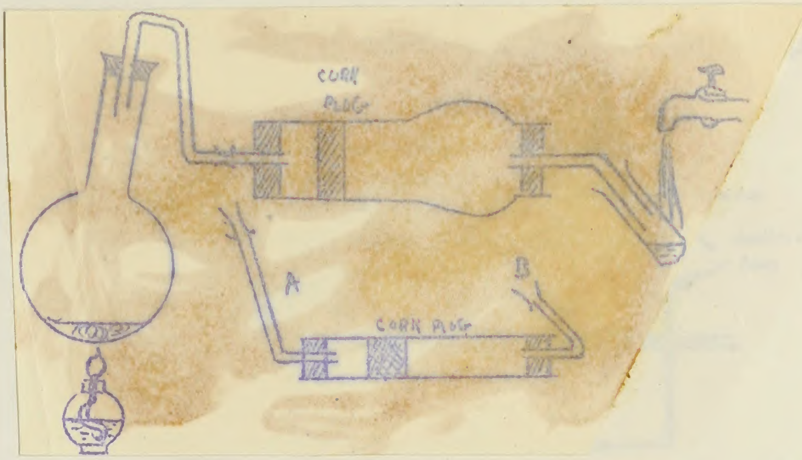


Figure 42. Only a physical change.

periment develops the idea for the steam engine if the rubber steam hose is attached to "A" and "B" alternately.

In Figure 43, cut a square of heavy paper at the corners, pin the corners at the center, and force a jet of steam into the cups. The energy of motion of the particles of steam should be sufficient to cause the windmill to rotate. Figure 44 provides a fine turntable for the steam jet to work upon. A similar device is arranged by providing a piece of glass tubing for the axle, a thread spool for the rotor and

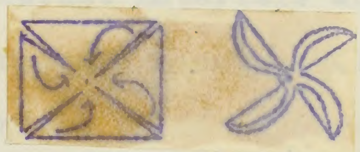


Figure 43. A paper steam mill.

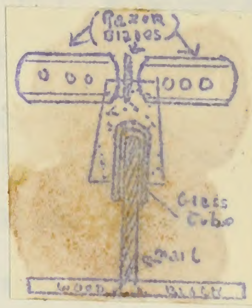


Figure 44. Steam turbine using razor blades.

strips of tin as steam cups.

4. Figure 45 illustrates a crude method of developing application of the principle used in the steam engine.

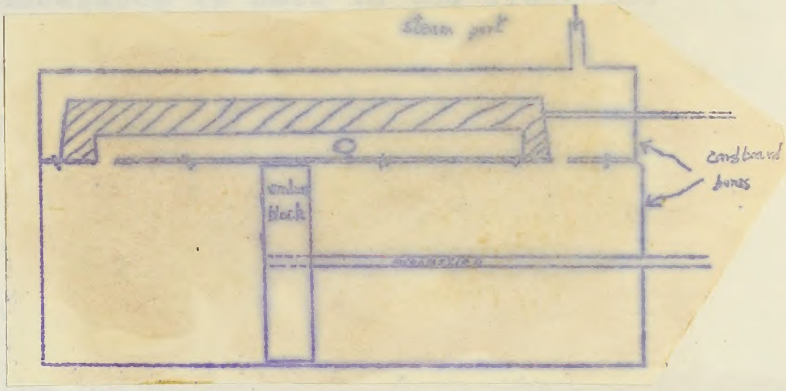


Figure 45. A cardboard steam engine.

The Activity of the Particles of a Material Is Transferred According to Its Tendency to Transmit.

A. <u>Conduction of solids</u>.

1. Two metal rods of different materials are suspended horizontally so that their ends are about a half-inch apart. At intervals along their length, as shown in Figure 46, thumb tacks are fastened by melted wax and a string. Place a candle or other burning heat source in between the ends of the two rods, and notice which of the thumb tacks drops off the first and which remains on the longest.

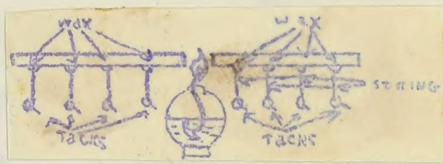


Figure 46. Transfer of heat by conduction.

2. Distribute to a group of people small rods of different materials such as glass pencil, copper, carbon, aluminum, tin, brass, lead, steel file, ring stand, scissors,

wood. Instruct each of the group to hold their object at a definite distance from the end which they are told to place in the flame. Which substance is held in the flame the longest; which the shortest length of time?

3. Place the flame of the heat source at "F" in Figure 47. Points "A", "B", "C", "D", "e", and "f" are equal distances from the point "F", and mark the place where drops of paraffin will be seen to melt at different intervals.

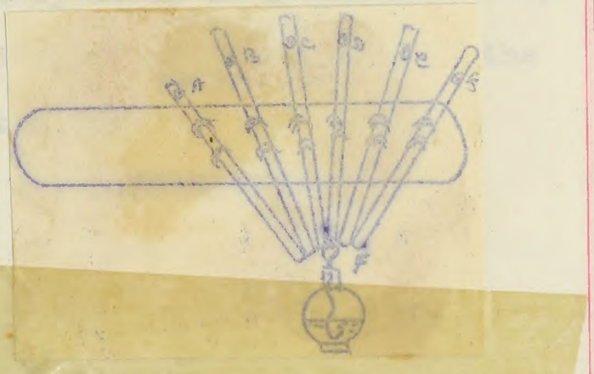


Figure 47. Solid conductors.

B. Water as a conductor.

1. Drop a few small pieces of cracked ice into a test tube, and insert a coil of wire to hold them down, and nearly fill the tube with water, as in Figure 48. Bring the water to a boil and watch what happens to the pieces of ice. If no ice is available the result can be obtained with satisfaction by holding the test tube in the hand while the heat is being applied.

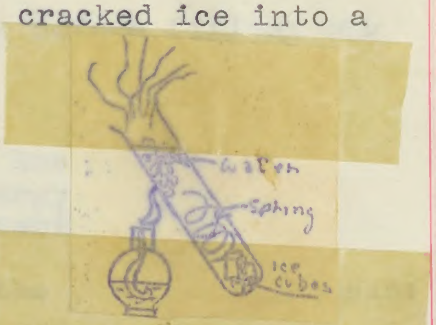


Figure 48. Heat transfer by conduction in water.

2. Find two wide-mouth bottles and stoppers fitted with thermometers. Fill one bottle with ice water, and the other, consecutively, in order not to crack it, with warm

water, hot water, and boiling water. Cork each and wrap each with wool felt or cotton batting. As controls, find two similar bottles and treat in the same way except for the wrapping.

3. Plug a small funnel by means of a medicine dropper. The funnel and jet of the dropper protrude through the mouth of a bottle into water in the bottle. Water in the funnel covers the bulb of the air thermometer. A layer of gasoline is put on top of the water, and a flame is applied there. As the gasoline starts to burn, the jet of the bulb dropper is watched for the expansion effect

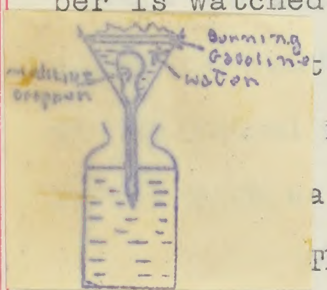


Figure 49. Water as a poor heat conductor.

would have upon the air in the bulb. Leakage may be prevented by packing before filling the ater.

The Degree to which Radiant Energy Is Converted into Heat Energy Depends upon the Type of Material.

1. Flatten out two pieces of the side of a tin can. At similar places in each sheet, as shown in the illustration of Figure 50, stick a short piece of chalk as follows. Dip one end of the stick of chalk into a pool of paraffin or sealing wax, and then hold the waxed end against

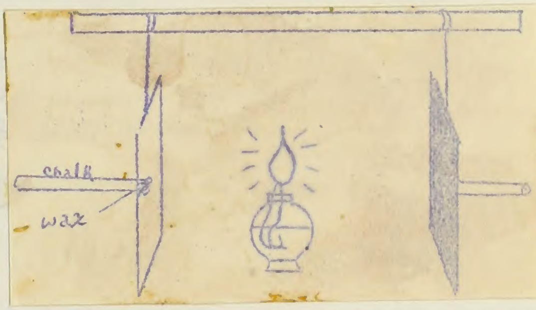


Figure 50. Radiant becoming heat energy.

the tin until the wax has solidified to a hard consistency. This fastens the chalk stick to the tin. Treat, the other chalk stick in a like manner. Then, to one sheet opposite the piece of chalk apply a coat of soot from the flame of a candle. Now, carefully suspend the two sheets from a bar so that they hang downward parallel to each other but separated by a distance sufficient to allow the flame of a heat source to be placed equidistant from each of the sheets and at the same level as the chalk sticks.

2. Wrap two thermometer bulbs with cloth of the same texture, one black or dark, the other white or light. Insert the bulb of each into a test tube, and expose both side by side to the sun. Observe and compare the thermometer readings.

3. Wrap a piece of white cotton on one test tube and a piece of dark cotton or black silk on another. Fit each test tube with a one-hole stopper and each stopper with a thermometer. Place each in the sunlight equal lengths of time and compare the temperature.

The Heating Effect of Radiant Energy Depends upon the Degree of Concentration of the Rays.

A. <u>Artificial concentration method</u>.

Show how a convex reading glass or lens can concentrate the sun's rays. Indicate this by the thermometer registration

in Figure 51. Or introduce a piece of paper for the thermometer. Try it upon your flesh or a match. Can you light a "safety" match this way?

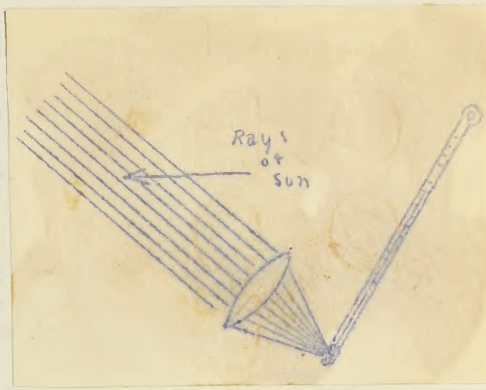


Figure 51. The burning lens.

B. Slant method of varying the concentration.

1. On a table where the sun strikes prop up two books in a diagonal position facing in, as in Figure 52. Cover each book with a piece of paper and lay it on top of a thermometer.

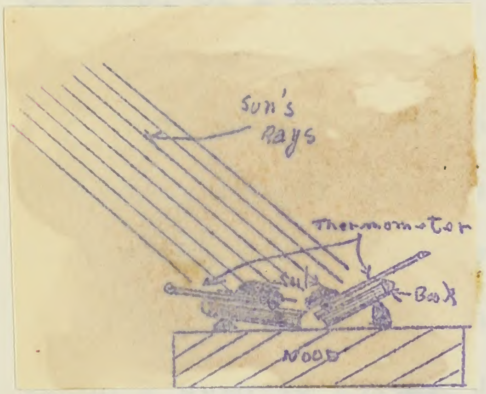


Figure 52. Hot equatorial rays.

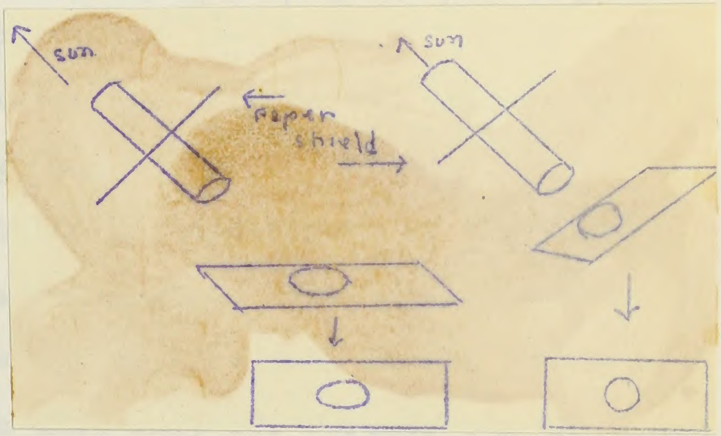


Figure 53. The slant rays covering a large area.

Cover the bulb of one thermometer with a little black dirt and the other bulb with a similar layer of sand. After 20 to 30 minutes of exposure make comparative readings of the thermometers.

2. In a darkened room hold a mailing tube in the path of a beam of sunlight or of an alcohol lamp. Catch the beam of light on a sheet of paper and have an assistant sketch a line around the part of the paper exposed to the shaft of

light coming through the tube. Hold the mailing tube in two different positions and repeat the process of drawing. Compare the areas outlined on the paper.

Light Rays Entering a Different Medium Slantingly Are Caused to Bend as They Enter or Are Reflected back into the First Medium.

A. Simple refraction.

1. Figure 54 shows how the introduction into the path of light rays, which are recording in the eye, of a substance different from the medium through which the rays have been travelling, may seemingly change the position and appearance of the objects from which the light rays are coming. The effect is studied by putting water into the bottom of a jar, on the bottom of which a coin is resting so that only its further edge is within sight. With no change in the position of the eye or jar, refraction of the light coming from the coin through the water into the air brings the coin into sight.

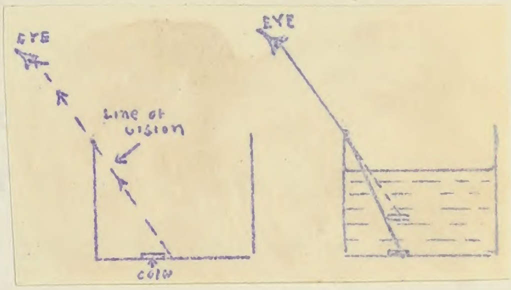


Figure 54. Raising the bottom by refraction.

2. In a darkened room aim the beam of a flashlight at a dark cardboard in which is a small slit. Behind the slit place a jug of water made milky with talcum powder. Close examination will show what happens as the small beam which penetrates the slit, enters the jug and its contents.

3. A line is drawn on a sheet of paper, and a pin

stuck at each end of the line. A triangular prism is laced on the paper next to the line so that one of its edges is diagonal to the line, which points towards the apex of the prism. Now, a ruler on the side of the prism away from the line is aimed at the line marked by the two pins. Of the two other pins placed along the line of sight of the ruler, one is stuck into the paper as near as possible to the prism's edge. After a sharp pencil has outlined the position of the face of the prism against the paper, the prism is removed.

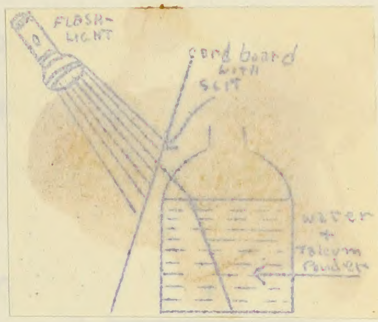


Figure 55. Refraction of a flash-light beam.

A line drawn between the two pins which were fixed at the opposite edges of the prism will mark the apparent line followed by the light in penetrating the glass medium.

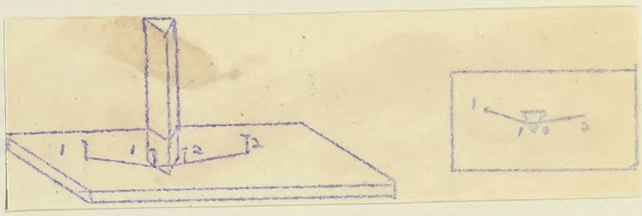


Figure 56. Refraction occurring towards the thick of the prism.

4. In addition, activities pertaining to the apparent bending of a stick in water help develop the principle underlying the applications of refraction.

B. <u>Light rays failing to enter are reflected</u>.

1. To develop the idea of the light rays failing to escape from a medium, hold a fish bowl, or aquarium above the observers' eyes. Look into the bowl and note the sur-

face reflecting light from various objects in the bowl.

2. When in a boat or a canoe one may observe only those objects in the water which are directly or nearly under the observer. He can not make out those objects which are off to his side. Why?

3. On a block of wood support a triangular prism. Hold an object above and at one side of the diagonal surfaces of the prism and find the position at which the object may be seen from the opposite diagonal side as an image in the base of the prism.

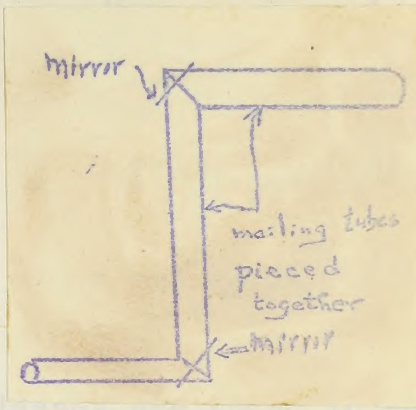


Figure 57. Basic structure of a periscope.

Images Formed by Convex Lenses Depend on the Distance from the Lens and the Amount of Curvature of the Lens.

A. Simple convex lens.

1. Hold a convex lens in a beam of sunlight in a dark room. Bring a sheet of paper beneath the lens and move it back and forth until the light seems to form a point. Scatter some dust or talcum powder in the path of the light beam on each side of the lens.

2. An optical bench can be improvised by supporting the necessary parts on the iron rod of a ring stand. Support the iron rod in a horizontal position. A meter stick or a yard stick are superior to the iron rod in that they provide

access to a measuring scale. Iron clamps provide the movable lens-holder supports, as in Figure 58. With an optical bench darkening of the room is not necessary. The optical bench is excellent for developing the ideas of the images of objects, and for images by convex lenses of different sizes and at different distances.

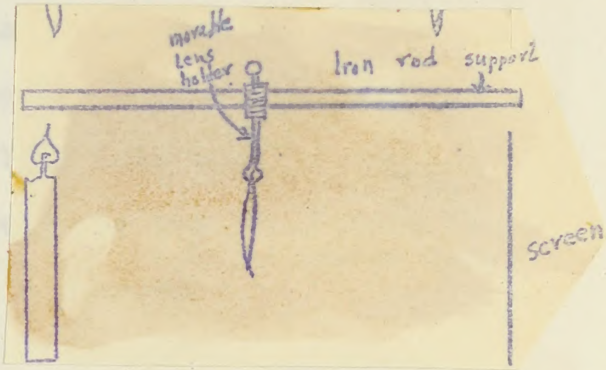


Figure 58. The optical bench.

3. Two three-inch watch glasses are faced in and are kept separated only by a very thin splint of wood. At one point water is run into the space between the watch glasses until it is filled. Then the splint is removed and the glasses are sealed thoroughly along their edges. The water lens is now used as would be any other lens. To show that it is the water which causes the refraction a similar arrangement is tried in which there is air, only, between the lenses.

4. The bulb of a spherical flask is filled with water and inserted into the light rays of a beam of light. It will change the direction of the light rays to bring them together at one point.

5. Using a pencil or piece of soft wood as a handle insert into the wood or eraser end the two ends of a short

piece of fine bare wire. Twist the wire into a tiny loop about three-eighths of an inch across and support a drop of water in the loop. Carry this small water lens into sun rays or arc lamp rays and concentrate the rays on a match or the bulb of a thermometer. See Figure 59.

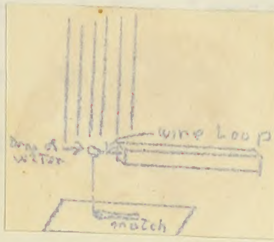


Figure 59. A water lens.

B. Telescope and microscope.

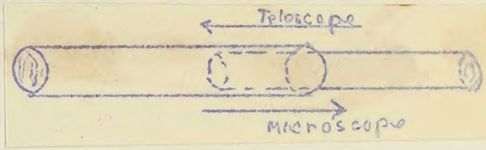


Figure 60. A simple telescope-microscope.

1. Hold at arm's length one of two lenses in the fingers of the left hand. Looking through this first lens with one eye note the appearance of the window. With the right hand hold a second lens so that you can see the window through both lenses. Move the lens in the left hand until the image becomes sharp.

This is well done on a miniature screen with the use of the optical bench. It is well also to use lenses of different curvature with the thicker one at the greater distance.

2. A simple telescope or microscope may be made from lenses and two mailing tubes of slightly different diameters. The mailing tubes are slit half way through in a plane perpendicular to the length of the tube. The slits are made near the ends of the tubes. The end of the device used depends upon the desire involved. The required length of the mailing tube can be found beforehand by making use of

the optical bench to determine the focal length of the lenses which are avilable. The length of each tube must be greater than the focal length of the lens of the greater convex curvature.

Light May Be Transferred to Place
of Need by Lenses and Mirrors

A. Mirror, projector, and periscope.

1. Set up a mirror on the window of a darkened room and cause sunlight coming in under the curtain to be reflected to the bench to make possible the examination of an object with a hand lens.

2 . Make a simple projector by combining a microscope and a 500-watt or carbon-arc projector. To get only parallel rays eliminate the condensing-lens unit of the projector. Shoot the light from the projector up through the microscope tube on to the ceiling by means of the small mirror at the base of the microscope. Take out the eye piece and the draw tube of the microscope because they cut down the size of the light beam.

3. Light may be taken around several corners. Use the reflection of a set of mirrors or prisms fitted to a mailing tube or lead pipe periscope.

Light Rays Travel in Straight Lines until
Contacting a Different Medium.

A. Light in straight lines.

1. Fit a cardboard to the lower sash of a sunny

window and cut a half-inch hole in the center of that part of the cardboard which is over the window pane. Cut the edges sharp. Otherwise, darken the room as much as possible and clap two dusty erasers together near the path of the light coming through the slit.

2. In a darkened room line up two cardboards in parallel vertical positions as in Figure 61 using a flash light or projection lantern as a strong light source. Punch a small round hole in the card nearer the light source. Clap erasers or blow talcum powder into the region of the cardboard and the light source.

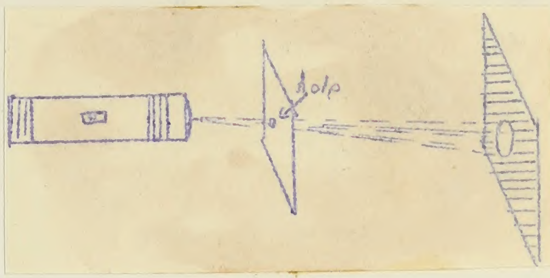


Figure 61. Light rays in straight lines.

3. Darken a sunny room with curtains, then replace one of the curtains with cardboard held on the frame by thumb tacks. Cut a small hole in the cardboard, admitting a beam of light. If the light beam is not easily seen, scatter chalk dust in its path.

White Light Is Composed of
Several Different Colors.

The extent of the refraction of each characteristic color ray provides a means of discovering this principle.

A. <u>Analyzing white light</u>.

1. Spray water away from you and upwards while having your back to the direct sunlight. Because of the

angles involved this will not work out if the sun is in a position directly overhead.

2. Dangle a glass prism or a flask filled with water in the direct sunlight. In each case observe the surrounding surface to see the color bands.

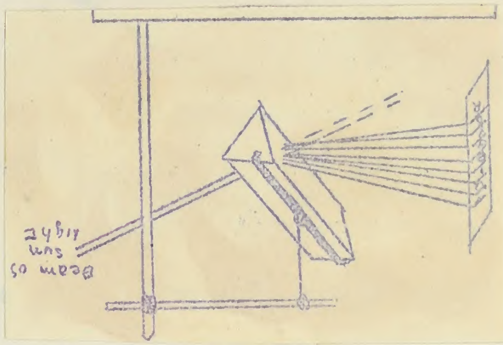


Figure 62. White light refracted.

3. In the absence of direct sunlight hold the prism or a water lens close to the eye to observe a distant object while giving the flask or prism a rotary motion.

4. In a dark room or at night, use, respectively, a carbon arc or an automobile headlight as the source of white light, as in the case above.

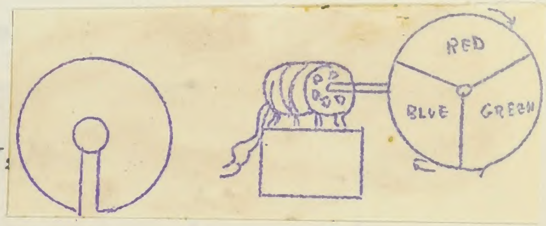


Figure 63. A color synthesizer.

B. <u>Synthesizing white light</u>.

1. Cut several different colored circles of paper as shown in Figure 63. Mount them overlapped, on the shaft of a small motor. When the disk goes very rapidly a grayish white is suggested.

Reflected Beams of Light Rebound
Like Balls Bouncing from a Wall.

1. In a darkened room allow a ray or beam of light to strike a mirror. Allow the light to escape from an arc or

the sunlight through a curtain with a hole in it. To make the ray more distinct clap together two dusty erasers, blow fumes of strong ammonia across a dish of strong hydrochloric acid, or shake a dry cloth saturated with talcum powder in the path of the beam before and after it strikes the mirror. Compare the angles which are formed by the plane of the incidence ray, and of the reflected ray, with the perpendicular to the mirror at the point of contact. Shift the mirror to vary the angles and carefully observe the new set in a similar manner.

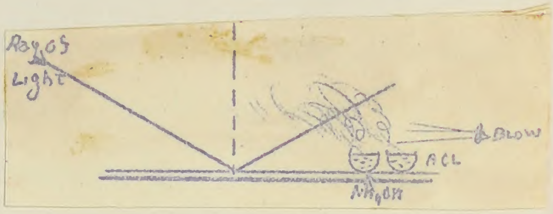


Figure 64. Incidence angle equals reflection angle.

2. At a height slightly above the heads of the people in the group seated, stand a large mirror parallel to the back wall, with the edges of the base horizontal, as in Figure 65. Move the top of the mirror slightly forward and back and have the people in the room decide what persons they can locate

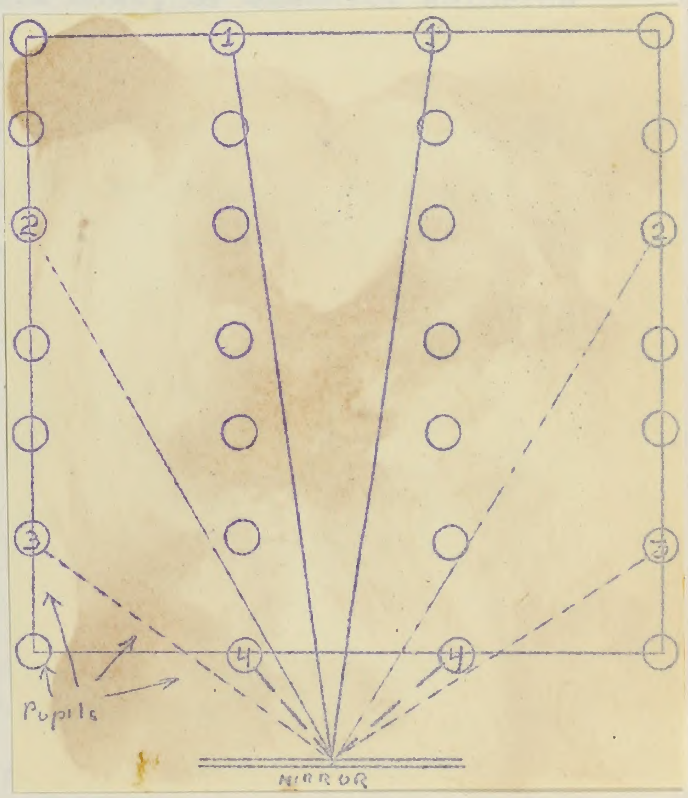


Figure 65. Regular reflection.

in the mirror. Remove the mirror after placing a line parallel to its face and through the center of this line, use a ruler to line up the people who could see each other in the mirror. With a protractor quickly estimate the size of the plane angles thus formed with the normal to the mirror. Then make mathematical comparisons of the size of the paired angles.

3. Find out what happens to a fine beam of sunlight or arc-lamp light in a dark room as it strikes the following: window glass, frosted glass, opal glass, glazed or unglazed paper. Use any one of the following as tracing mediums: dust, talcum, chalk dust, or ammonium chloride suspension (see Figure 64).

4. At one end of a large piece of drawing paper draw a simple geometric design, as shown in Figure 66, a triangle. Locate its image in the mirror by the method below. Place pins at each of the corners of the diagram and draw a line approximately in the middle of the paper. Set a plane mirror upright on the paper so that its silvered edge is above and along the line.

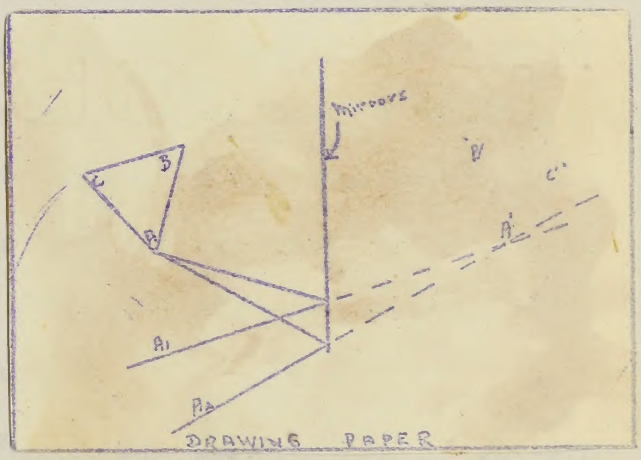


Figure 66. Image and object.

Looking into the mirror locate the pin at one of the corners and using a straight edge draw a line at the image of this pin. Label this line "A1". Then observing from a different location draw a second line at the same image and call it "A2". Proceed in the manner above and draw two lines for each of the pins to be located. Then remove the mirror. The corners of the image are now located by finding the place of the intersection of each pair of lines. Make careful comparisons of the image and object in respect to length of sides and distance from the mirror.

Light Rays from Different Parts
of an Object Passing through
a Point Become Inverted.

1. Take the film box out of a box camera, set the diaphragm at "time exposure", shield your eyes from all light but that entering through the diaphragm opening, and note the appearance of objects at a distance of 25 feet.

2. This can be repeated by holding a foot-length cardboard box to the eye after cutting a small smooth hole about one-eighth inch in diameter in the base of the box.

3. Cover one end of a cylindrical or box-like cardboard container with transparent tissue over one end and with heavy black paper over the other end. Fasten a layer

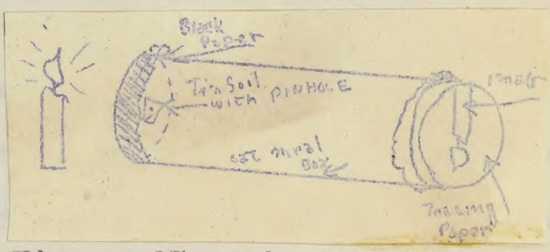


Figure 67. A box camera.

of tin foil over the black paper, and stick a pin through

the foil to make a small round hole in the foil. After setting a lighted candle on the bench in front of the tin-foil side of the container, darken the room and view the transparent tissue. See Figure 67.

This is done as well using a cigar box lengthwise. The wooden frame makes possible a firmer stretching of both the paper end coverings. It is better to cut away from the box only the end used for the transparent tissue. In the other end cut a hole in the wood about an inch in diameter. Cover this with the tin foil and punch a pin into its center.

The Intensity of Illumination
Varies Inversely as the
Square of the Distance.

A. By photometer.

1. As shown in Figure 68 it is possible to move to different measured distances from the waxed paper, a small light source inside an opaque container. A cigar box standing lengthwise or a stove pipe has its end covered with heavy paper the center of which has been replaced by a circle of waxed paper.

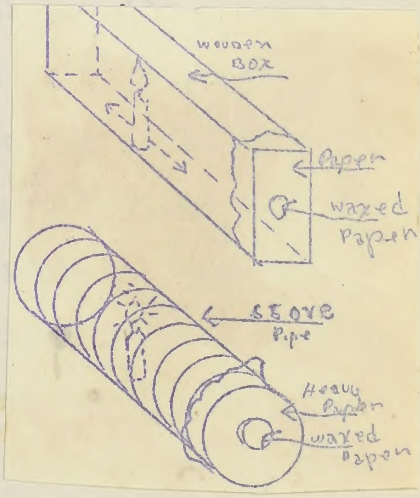


Figure 68. Photometers.

If the light source is a standard candle it becomes possible to do actual intensity of illumination experiements. A dark room is necessary for these procedures.

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Figure 68. Photometers.

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B. By more accurate determination.

1. Development of the actual mathematical statement may come from the use of the apparatus shown in Figure 69. Take four cardboards and cut out of their centers, areas, respectively, of 1, 4, 9, and 16 square inches (square centimeters would be as appropriate).

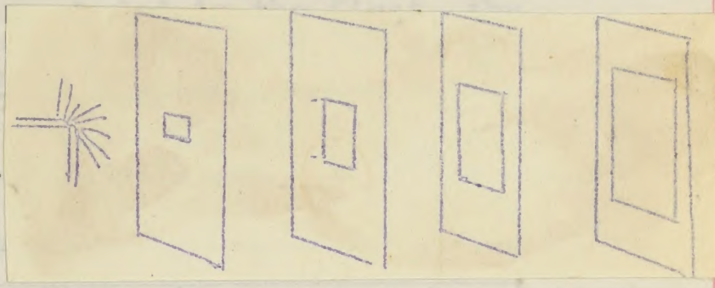


Figure 69. A definite amount of light covering as area equal to square of the distance at each step.

Stand these cards in a vertical position, one foot apart, the line being a distance of one foot from the light source which should be as small as possible. A small carbon arc, a covered flash light, or a beam of sunlight provide a source superior to a lamp flame. If the beam of light passing through the hole of the card nearest to the light is such that at each position of the succeeding cards, it just fills the space cut away, the apparatus is properly arranged.

2. Using the same type of light source, move a piece of cardboard to the following positions between the light source and the blackboard: (1) next to the blackboard; (2) half-way between the light and the board; (3) one-third of the distance from the light to the board; and (4) one-quarter of the distance from the light to the board. Table 1 illustrates one method of filing the data and the method of

collecting this data is explained as follows: At each posi-

Table 1. Column (4) expresses the relative intensity of illumination of the card at each of its positions. If the shaded area at the second position is four times that shaded in the first, the intensity of illumination at position "2" is four times that at position "1".

Experiment position number.	Distance as a fraction.	Square of inverse of fractional distance.	Intensity of illumination.
(1)	(2)	(3)	(4)
1	1	1	1
2	½	4	4
3	1/3	9	9
4	¼	16	16

tion careful measurement is made of the area of the blackboard shaded by the cardboard and an attempt is made to mathematically reduce these comparative areas to the nearest simple fractions possible.

Sound Waves in One Body Set up Similar Waves in Contacting Bodies.

1. In Figure 70 is illustrated a commonly used apparatus. Often this experiment is claimed to be

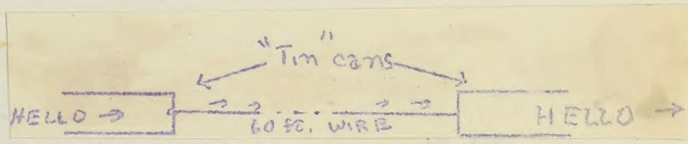


Figure 70. The toy telephone.

the foundation of the principle of the phonograph. A person whispering into the open end of one of the cans may be heard by a person at the other end. Cereal boxes will do as well as the tin cans indicated in the illustration. The connecting cord may be satisfactorily made from fine rope, or bare wire; it must be pulled tightly. To fasten the

cord into the box use a knot, a headed nail, or a button. A piece of some solid material larger than the hole in the cans has proved satisfactory. By using the covers, only, instead of the whole deep can, more convenience of manipulation is secured.

2. Examination of a phonograph record with a reading glass reveals that apparently smooth ridges and hollows are comparatively rough. It then seems easier to understand that the needle which cut the model was, while in the process of cutting, in a state of varying vibrations.

3. Strike a tuning fork and place the handle against the top of a hollow box one end of which has been removed. Repeat the experiment with the end back in place and notice the difference in the degree of resonance. Hold the fork's stem against any large hard surface. The solid and the air, in turn, are set into vibration. See Figure 71.

4. Listen for the tick of a watch held in the air. Lay the watch on the tables, and notice the increased intensity of the sound.

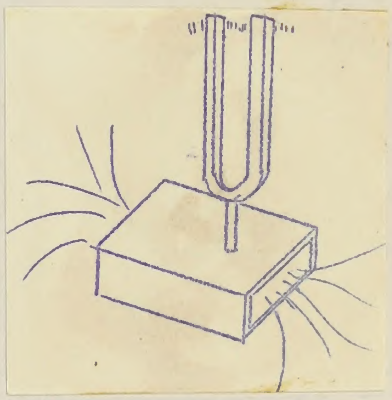


Figure 71. Resonance.

5. Even the light material air sets other bodies into vibration; especially is this noticeable if the other body is so constructed that its natural vibration rate is the same

as that of the first body, as shown in Figure 72. The usual procedure is to place a resonance box under the second fork to amplify the sound waves of its slight vibrations. As is shown, if the second fork is not constructed so that its natural vibration rate (of its fundamental) is the same as that of the first, air is an inefficient means of effecting the transmission. The natural vibration rate may be lowered by tying an elastic to the tip of one of the forks.

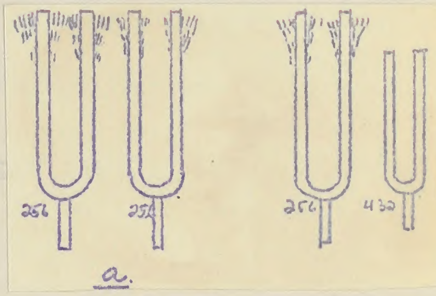


Figure 72. Sympathetic vibrations in like forks not unlike.

6. At a pond have another person clap together two stones under water at some distance from your ear which is also immersed in water. This will help to understand the detection of sound signals in foggy weather.

7. Touch a vibrating tuning fork to a strip of paper, to a suspended pith ball, or to the surface of a container of water. Lightly tap the tuning fork in Figure 73 with the rubber end of a pencil. This causes its prongs to move sufficiently, in turn, to knock the pith ball for a considerable distance.

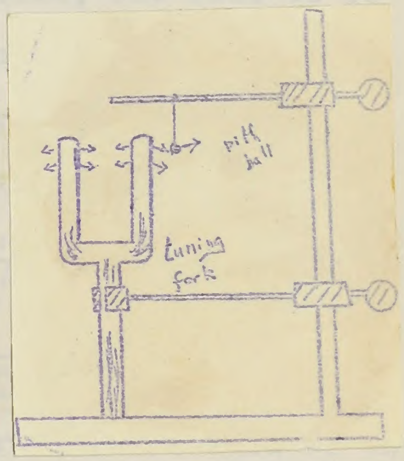


Figure 73. Real vibrations.

As in Figure 74, resonance and the reinforcement by sympathetic vibrations may be secured as one or two like forks mounted on resonance boxes at a considerable distance from each other are forcibly set into motion.

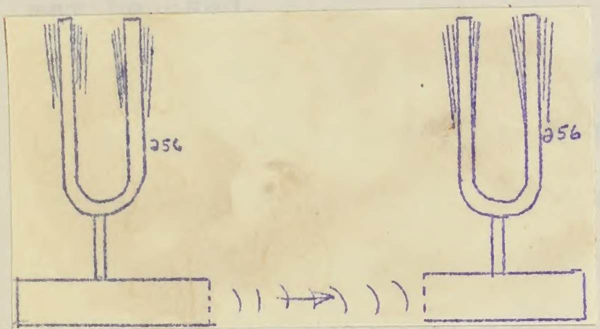


Figure 74. Reinforcing sound waves and sympathetic vibrations.

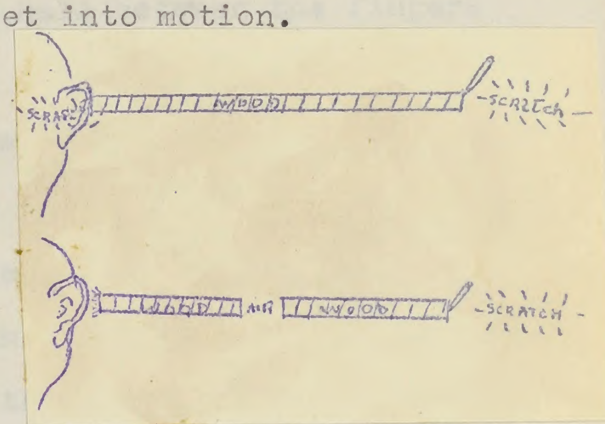


Figure 75. Solids versus gases as sound transmitters.

9. That solid materials are better as sound transmitters is shown by performing the simple procedure of Figure 75. In the upper part of the illustration the sound waves are apparently carried through solid, but fail to be carried as well through the air interval.

10. Sing loudly a moderately high note into the piano and listen for the sympathetic vibrations.

11. Rotate a phonograph record and, as it whirls, touch the grooves with a pin or needle held in the teeth. Instead of these use the edge of a piece of stiff paper or any other sharp articles like a nail file. It is not necessary to have anything more elaborate as a turn

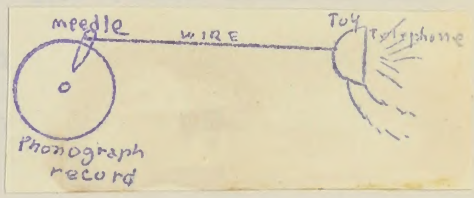


Figure 76. The idea of the phonograph principle.

table than the end of a sharpened pencil which will readily be found to protrude up through the hole in the center of the phonograph record. The contraption of Figure 76, with the toy telephone and a needle held between the fingers may be used.

12. Clamp a hack-saw blade in a horizontal position an inch or so above a flat surface. By means of wire or thread firmly fasten a stylus vertically nearly at the extended end of the blade. This is shown in Figure 77. Place a sheet of paper under the stylus, set the blade to vibrating and quickly pull the paper out from beneath.

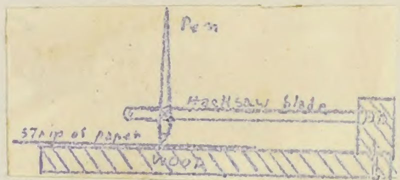


Figure 77. The record of vibrations.

13. In Figure 78, there is illustrated a simple method of showing how the energy of sound waves may become the energy of dancing dust particles. The top of any small cardboard box is replaced by a tightly-bound layer of transparent tissue. The other side of the box pierced with a glass tube which in turn is connected with a source of sound waves by the funnel and rubber tubing as shown.

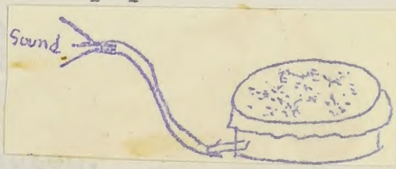


Figure 78. The dust particles dancing.

Vibrating Bodies
Cause Sound Waves.

1. Stick a needle or razor blade into a board, Snap it with your finger. Notice how the sound is lost as

the vibrations are lost to the vision.

2. Repeat holding the needle between the teeth.

3. Tightly stretch a wire or elastic between two supports. Pluck the band or wire and make careful observations like those above.

4. After the vibrations of a tuning fork have apparently died away, hold an edge of thin paper against one of the prongs and then place the handle of the fork firmly against the top of a resonance box. Hearing both the light singing of the paper and the reverberations of the resonance box is evidence that the fork continues to vibrate.

The Number of Vibrations per Second Determines the Pitch and the Frequency Depends upon the Length, Mass per Unit Length, and the Tension in the Body.

A. Pitch and frequency of vibration.

1. Compare the pitch of the tone produced by a tuning fork vibrating 256 per second with that of a fork having a different frequency.

2. Again use the experiment of the clamped hack saw blade to find out what happens to the pitch by loosening the clamp. Then make an ink sketch of the vibrations with the blade produced, first, a low tone, and second, a high tone. To make the sketch refer to the discussion in connection with Figure 77.

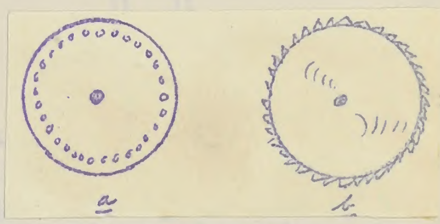


Figure 79. Pitch versus frequency.

3. Prepare a sheet of drawing paper like that of Figure 79. Fasten it to the axle of a toy motor. When the paper is rotating rapidly, blow a stream of air through the row of holes. Then by changing the speed of rotation determine what the effect upon the pitch is of a different frequency.

Cut slight notches in the card. This makes an imitation circular saw. Set up the apparatus as above and hold a light piece of paper against the rotating blades.

Recall the changing pitch of the circular saw as it slows down in penetrating a thick piece of hardwood, and recall the rising pitch as the saw regains its speed when opposed by less resistance.

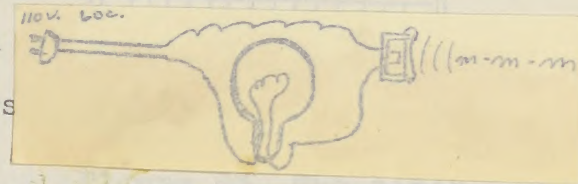


Figure 80. The hum of 120 vibrations per second.

4. Use the hook-up shown in Figure 80. With the plug from a floor lamp disconnected, sever one of the wires of the cord. Fasten the two ends of the cut wire to the terminals of a telephone receiver and put the plug back into its socket. This connects the receiver in series with the floor lamp. Use the incandescent bulb as the circuit breaker and current indicator. Incidently note that it is important

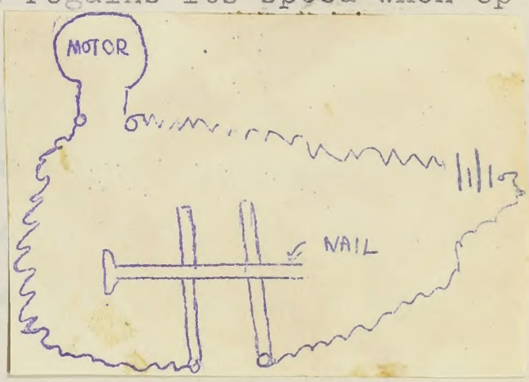


Figure 81. Speed and frequency of the humming sound.

to have the bulb in the circuit to provide the resistance which prevents the telephone receiver from burning out. The very definite pitch of the hum which is heard is the 120 frequency pitch.

6. Make an improvised motor rotate fast and at variable speeds by use of the rheostat arrangement of Figure 81. The hum at different speeds is indicative of the relation of frequency and pitch.

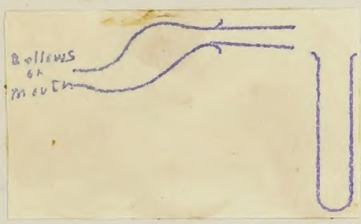


Figure 82. An air column vibrating.

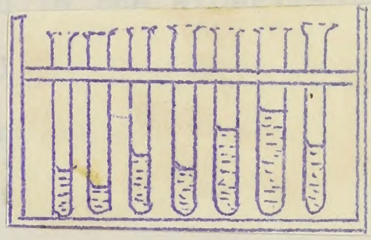


Figure 83. The pitch depending on length.

B. <u>Determining frequency</u>.

1. Arrange a set of eight like test tubes in a rack each containing a graded quantity of water. Then blow across the tops of the tubes from the mouth directly or with the apparatus of Figure 82. After a little adjustment it will become possible to reproduce with a degree of accuracy a scale of notes.

Fill each of eight water glasses to levels proportional to those in Figure 83. Tap each with a piece of silver and determine the relation between length and the pitch.

2. Secure two test tubes of different internal diameters and blow into or across their openings until a tone can easily be obtained. The longer tube is filled with water

until the length of its air column is the same as that of the shorter tube. Then the pitch of each is observed to find out the degree of importance of the relationship of frequency and diameter of the air column.

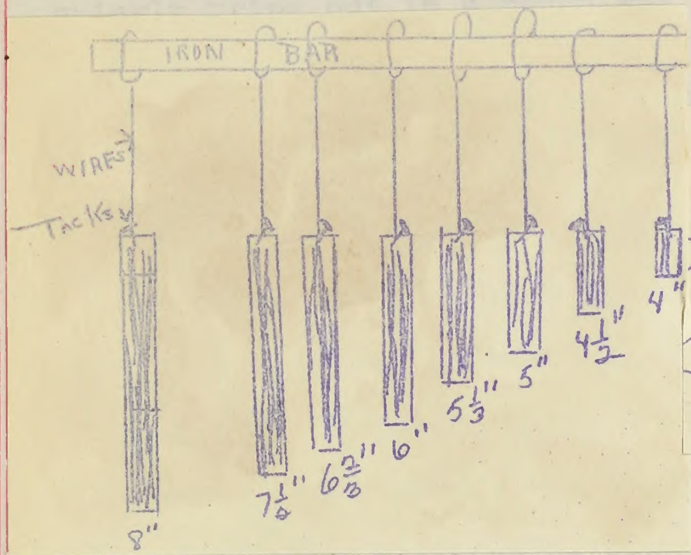
3. Cause the air column of a six-inch test tube to vibrate by using blasts of varying intensity. Determine what relation, if any, exists between the pitch and the force of the vibrations. Here, and in the experiments preceding, small bottles will do as well as the test tubes.

4. What does the trombone player do to the length of the air column of his instrument to play a low note? With a toy flute find out what type of pitch is obtained as the air column is vibrated first, with the top hole, and second, with only the bottom hole "stopped".

5. From a piece of hardwood measuring four feet by two inches cut eight small pieces of the wood the length of which are indicated in Figure 84. Suspend them from a bar by light cord. Now, if these are tapped lightly with a hammer, the tones produced respectively will help to develop the idea of the relation between length and pitch.

6. A home-made sonometer can be quickly put together with instrument strings and a like number of small pulley wheels. Secure the string to a hook in one end if a flat board, stretch it across and over the length of the board and down over a toy pulley fastened into the board so

that small weights can be added to change the tension in the string. Small bridges, numbered "1" and "2", in Figure 85,



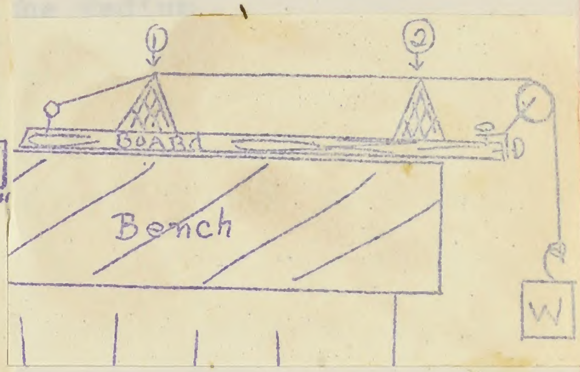


Figure 84. Length versus frequency.

Figure 85. The simple sonometer.

may be made of solid glass or any hard block. This improvised sonometer presents many possibilities. From it all the general laws of vibrating strings may be ascertained.

If no pulley wheels are available a short glass tube rotating around a "finishing" nail as an axle, will provide a useful substitute.

7. An improvised sonometer board of a simple type is shown in Figure 86. By merely twisting the wood screw, "A", the tension is changed; by running the fingernail down the string from "A", the length is changed by introducing different string, the cross-sectional

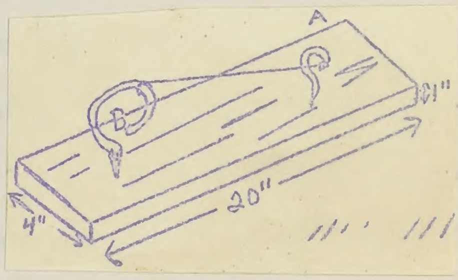


Figure 86. Pitch versus tension.

area is changed. This device is therefore as useful in general as the commercial sonometer. Use can be made of it to quickly bring out in a rough way the simple relationships.

The Density of the Medium
Determines the Speed
of the Sound Waves.

A. Speed in air by direct methods.

A person armed with a gun and some "blank" cartridges, goes to a point at some distance from, yet in view of, another person. The observer, using a stop watch measures the time interval between seeing the flash of the gun and hearing the explosion. The distance between the two persons, measured in feet, is divided by the number of seconds and fractions thereof, to approximate the velocity of sound waves at that temperature. For checking several sets of observations should be made.

This procedure may be imitated by using instead of the gun's flash alone, a flag large enough to be easily seen at a distance of a half-mile. In this way the experiment may be done during the daytime. However, additional error creeps in because it is usually necessary to have another assistant who signals with the flag as the gun is fired. Instead of a stop watch, a "seconds" pendulum may be used satisfactorily.

B. By resonance.

In Figure 87 a tuning fork, vibrating, gives off sound waves, which by the use of resonance in the air column, pro-

vide a means of measuring the velocity of sound in air. The illustration indicates that water added to the graduate changes the length of the air column. The experimenter keeps the fork in the state of vibration in the position shown, as he changes the length of the air column, and listens for the re-inforcement of the sound waves. When the maximum resonance is heard take careful measurement of the length of the air column from the water level to the edge of the lower prong of the fork. It is approximately 13 inches for a fork of 250 vibrations per second.

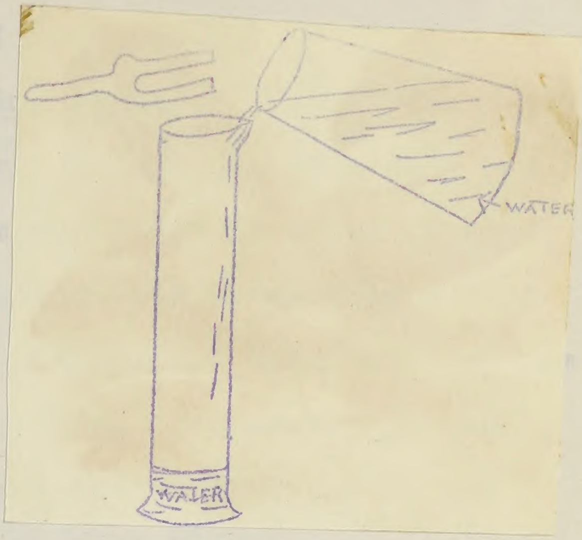


Figure 87. Resonance used to find sound speed.

The tone of any string if its pitch or frequency of vibration is known may be used instead of the tuning fork. A paper cylinder which just fits around the glass cylinder may be moved up and down as a means of changing the length of the air column instead of having to pour water into and out of the cylinder as the determination of the length for maximum resonance proceeds. To compute the speed of the sound waves in feet per second, multiply the "length" in feet by four and then by the vibration rate. The diameter

of the air column is of little value unless the air column has a very large measurement in diameter.

C. Speed of sound in other matter.

1. To develop recognition of the fact that the speed of the sound waves is much greater in water or steel than in air, go to a railroad track where there is a long straight stretch. One person strikes the track with an arm motion swinging a hammer or a stone. The observers take careful measurements of distance intervening and of the time interval required for the waves to travel in the different substances, steel and air.

CHAPTER III

NATURAL FORCES OF ATTRACTION AND REPULSION
ARE IN CONTINUAL INTERPLAY
AMONG ALL BODIES IN THE UNIVERSE

The Shape, Position, and Motion
of the Heavenly Bodies
Express Adjustment to
Natural Forces between Them.

A. All bodies in the universe attract each other.

1. The apparatus for this experiment is a pan of still water and pieces of cork of varying sizes, Float two of the larger pieces of cork about an inch apart and place a smaller bit between them. Notice the natural attraction of the pieces for each other.

Instead of using these larger bits, scatter some filings of cork over the quiet surface. Then push one of the largest pieces slowly through the small scattered particles and notice how the smaller pieces are drawn to the larger one.

2. That natural forces operate to hold planets (and stars) in their places and to keep them in their motion, may develop from remembering the youthful experience of twirling on a rope a horse-chestnut to be thrown for distance. This shows that such motions require definite forces in action, and

portrays probable result of the release of these forces.

Fasten a yard length of string to a rubber ball about two inches in diameter. Whirl the ball in a vertical plane. Have the group ask themselves the question: Is it necessary to use additional force to the whirling motion to cause it to go on a flight after it has begun twirling?

3. Pour a pan of water into a drain. What shape do its parts take as the length of free fall increases? What is the shape of hailstones; how is lead shot for air rifles or shotguns made? The freely-falling liquified "lead" solidifies before it hits water and is thus caught in a spherical shape. The particles (molecules) of any fluid, either a gas or liquid, being free to move in this fluid state, have sufficient attraction for each other as to cause the formation of the mass into the most compact shape, shperical. This force is sometimes called the "surface tension" of a liquid. These are examples of natural forces at work.

B. <u>The arrangement and motion of heavenly bodies express their adjustment to the natural forces in operation.</u>

1. The ventilation box with its removal glass side may be used as an astral lantern after it is equipped with an electric light socket. Substitute for the glass side, or fit inside the glass cover, a piece of glazed paper in which the constellation to be studied has been diagramed.

A small box, four inches on a side is fitted over the end of a flash-light lamp. The side opposite the bulb is open

to hold star charts. These are cut from black paper a trifle larger than the box so that when the box cover with only its edge remaining is replaced, the chart will be held firmly. Any constellation may be marked out by placing the relative positions of the principal stars in the constellation and at these points pricking holes with a pin.

2. Three balls of unequal size are fastened in the position indicated in Figure 88. Two are attached to a strip of wood supported by a block of wood, and a third is fastened to the end of a curved wire "a" which pivots about the end of the top strip of wood. This, though crude, helps the pupil to visualize the solar system.

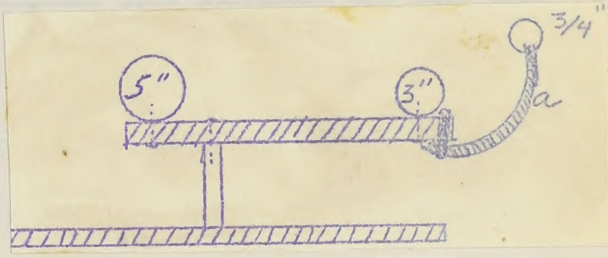


Figure 88. A crude Planetarium.

3. Fasten a nail to a bench and from this center, which should be marked "sun", rotate a tennis ball which has been tied by an elastic string. The distance from the nail to the circumference should be varied so that the orbit which is formed is slightly elliptical as is the case with the planets in the solar system.

Impale a tennis ball with a needle of sufficient length. The ball indicates the position of the sun and a stylus of suitable material marks the path of a planet. The stylus is held away from the rotating needle by means of an elastic

the tension in which is varied to assure the tracing by the marker of the ellipse. A piece of chalk, a pencil, a pen, or a crayon may be the material for the stylus. A nail may be used for the needle, a string or wire for the elastic, and any type of ball may be substituted.

C. <u>Effect of varied positions and motions of the sun and moon upon the impressions of earth peoples.</u>

1. Mark on a tennis ball an equatorial line and an "x" to mark the location of the observer. Pierce the ball by a long knitting needle and keeping the axis of the ball always in the same plane cause the ball to rotate on its axis while being carried around a strong light. At several positions in the circular path stop the ball and take careful observations of the fraction of a total rotation during which the point "x" is exposed to the light. This will illustrate the changing lengths of day and night at various times during the year.

2. "Type of season" may be developed as an idea with the completion of the experiments concerning the transformation of radiant to heat energy as depending upon the concentration of the sun's rays. See Figures 52 and 53. Examine at various positions of the cycle, in the above set up, the directions of the sun's rays as they strike various points of the "earth's" crust. Greater clarity of the idea results if as many balls-on-needles as there are seasons are represented, and if their unexposed areas are shaded in. A cruder

application of this idea is obtained as an elliptical orbit is chalked on the floor, use is made of a floor lamp as the light source, and a large impaled ball, such as a basketball, represents the globe. A real globe is good to use in that the problem of the location of the observer is easier.

3. How the sun marks the time is an easy idea to develop. An impaled tennis ball is marked from the base of each "pole" by twelve equally-spaced concentric circles which make 24 spherical-arc areas similar to the earth's time belts. To make these belts draw an ink line under an elastic which is fitted to the ball. Shift the elastic location each time cutting the remaining area in half until four such circles cut the ball into eight areas. Then divide each of these areas into thirds by applying the elastic circle twice in each of the areas.

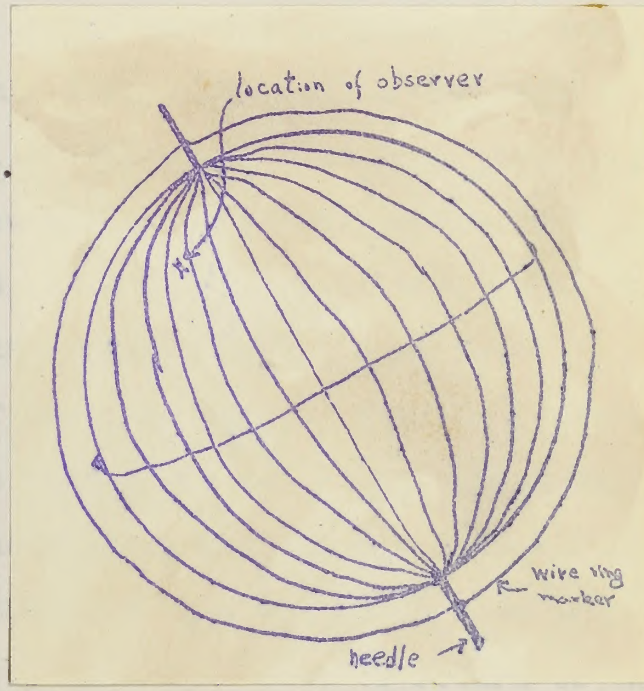


Figure 89. Time belts by the sun.

Mark a location mark "x", and by twisting the ends of a light copper wire around the opposite poles make a longitude marker which is free to move as shown in Figure 89.

The marker remains stationary with one edge always toward,

the other away from, the light source. The ball begins its rotation with "x" directly under the wire marker which is next to the light source. A count of the time of day is kept by saying "One P.M.", "Two P.M.", "Three P.M.", and so on as the different time-belt markers pass under the longitude marker.

Principles concerned with the width of a time belt evolve first in degrees, from the knowledge of the number of degrees in a circle; and second in miles, by applying a mile scale to the latitude circumference at any particular place desired, as for example, at "x". This mile scale can be made with some accuracy for any ball, on the assumption that its, longest circumference is 25,000 miles. If the actual measurement of its "equator line" is found to be 25 inches a map length of one inch represents an earth distance of 1,000 miles.

4. The phases of the moon are illustrated as follows: Darken a room except for an arc or bright incandescent bulb which is located at the front. Suspend a basketball on a wire and pass it around the room from the front, down the left side, across the rear, and up the right side to return to the starting place. Fairly reliable imitations of the new moon and full moon positions result from examination of the appearance of the ball while in the front and rear of the room, respectively. A greater likeness to the appearance of the moon in its first and last quarters, respectively, can be had

if the light is held underneath and to the right of the ball on the left side of the room, and underneath and to the rear when the ball is at the right side of the room. The perspective is improved if, instead of carrying the ball around the room, it can be pulled around as it dangles from a wire strung along the top and sides of the room.

5. The idea of the moon as a possible cause of the tides may be developed as an idea in two ways. The necessary material found on a calendar, in an atlas, or in the weather report of a city on the sea coast, is used as follows: Make a table of the height of tides every day for a month. Select the dates of highest and least high tides with the moon phases. It will be found first, that the greatest high tides come twice in a month at about the date of the new moon and full moon, second that the least high tides occur approximately on the date of the first and last quarters. Actual observations will bear out the claim.

6. If the time required for the rotation of moon and earth are compared, it will be noticed that the moon lags behind the earth's turning by a small amount of time each day. If the number of minutes required for the earth's rotation, 1440, be divided by the number of days required for the moon's trip around the earth, 29.5, the number of minutes by which the moon falls behind each day will result. (Apparently the moon's speed varies because the answer to this

computation only approximates the average daily retardation). A check up with the detailed weather report over a period of many days shows that the moon averages this lag--48 minutes--in rising every 24 hours, and that the average retardation of successive high tides (occurring twice in each day) is half of the 48 or 24 minutes. These observations make it easier to accept the explanation of the moon as a cause of the tides of the earth.

D. To account for the spherical and slightly bulging shape of heavenly bodies.

Natural forces at work during the formative years of the earth explain the shape of the earth and most other heavenly bodies. Recall that the earth at one time was supposed to be in a gaseous state of matter and then a liquid, and put with that the statement explaining why a freely falling fluid assumes a spherical shape. The matter of the attraction of like molecules which are free to move is given some attention in the first two pages of this chapter. In addition:-

1. Take two thin strips of cardboard, or of semi-stiff paper, a little longer than a foot, and make them assume a circular shape by bringing the ends together. Insert a long needle through the ends and middle of the strips and mount a clasp and a paper washer to hold the pieces of paper in place. The middles of the strips are worked up and down the needle to minimize friction and leave them more free to move against the needle. The device is twisted in the fingers

or between the palms of the hand, first, above the point of applied power, and then below. Pieces of wax, paraffin, wire, or gum make satisfactory washers. Thin strips of flexible metal or springy wire can do as well as the cardboard. The strips may be pinned, glued, clipped, welded, or riveted together. A thin stick, a long nail, pipe, or spike may take the place of the needle.

Natural Pressure in Fluids Is
Proportional to the Depth
and Kind of Matter Above.

A, Air exerting pressure.

1. Fill any vessel having a flat-top opening with water (a tumbler is satisfactory). A cardboard soaked in water is laid flat against the top of the vessel and is held in place with the hand while the dish is being inverted. Carefully the hand is taken away. The water is held in the vessel in this unusual position, by air pressing on the card.

In the above procedure, it is not necessary with small vessels to hold the water in while the dish is being inverted unless they are only about half full.

A piece of fine cheesecloth over the jar does as well as the cardboard, and is more challenging.

2. A tube is inserted into a vessel of water. The thumb is clasped over the upper end and the tube lifted from the water. Again, suck the tube full of liquid and cover the upper end.

3. Any "tin" can with a small opening can be crushed by air pressure easily. Drive out the air and then tightly cover. The can is heard to crinkle and is seen to fall in if there is no air leakage. The air may be expelled by replacing it with steam coming from some water boiling at the bottom of the tin. In this case after the can is covered while filled with the live steam, place it under the cold water tap. The steam condensing reduces the inside air pressure and the desired result occurs.

4. Stretch the mouth of a rubber balloon over the large end of a thistle tube, small funnel, or a side arm flask. Put the open end to your mouth and extract some air.

B. <u>Water exerts pressure which is proportional to the depth.</u>

1. Close the end of along glass tube. Insert the open end into water in a deep transparent vessel. By holding the tubing next to the side of the larger vessel one can make careful observations of the height of the liquid at progressive depths of the tube's open end.

2. Put water in the bottom of a graduate so that when the graduate is inverted the water will fill it to the first mark. Make a temporary plug to cover the open end of the graduate to prevent the measure quantity of water from escaping as the graduate is inverted into a vessel of water. Since the vessel is transparent the effect of depth on pressure can be measured at definite intervals. Another way to

achieve this condition of water up to a certain mark in the inverted graduate, insert a piece of rubber or glass tubing under the rim of the graduate, and applying the other end of the tube to the lips, extract enough air from the graduate's interior to enable the air pressure outside to push the water up as far as desired.

3. Continuously feed water to a metal can conspicuously placed in front of a drain or sink either directly from the tap, or indirectly by a hose from the tap. The can has three, or more, holes punched by a nail at regular height intervals. These holes act as exits for the water being fed in at the top of the can. To observe the pressure-depth relationship, note the distance each jet of water travels horizontally from the can. To compare volumes escaping from each exit, for equal lengths of time place a jar under each jet.

4. Pour a little water into one side arm of a "U" tube which thereby can act as a manometer or pressure indicator. A satisfactory "U" tube is easily improvised from glass and rubber tubing. Use a rubber tube for attaching and cover the wide end of a thistle tube with a rubber dam--toy balloon, bathing cap--and then attach it to one end of the manometer. Insert the covered end of the thistle into a deep vessel of water. A little ink or other coloring matter will make it easier to observe the level of the liquid in the "U".

C. Measuring air pressure.

1. Torricelli set up a glass tube which he had

ready to connect to another tube, closed at one end and 34 feet long. He filled the long tube with water, tightly fastened it to the short tube by means of rubber tubing and string, and inverted it into a pool of water. The water was found to stay up. This procedure can be followed out as a stunt.

2. A glass tube about three feet long, open at but one end, is filled with mercury. Cover the open end with the thumb and invert the tube into a shallow dish of mercury. It becomes much more meaningful if the tube held at its upper extremity is shifted from position "b" to each of the side positions "a" and "c" shown in Figure 90. Make observations of the actual vertical height of mercury above that in the base dish. The Torricellian tube can be made from shipment-length tubing if one end is melted so as to allow it, in solidifying, to close the opening. Hard glass tubes can be melted by a brief exposure to the heat of the improvised arc light, but this tube must be carefully filled if the weakened (by the carbon particles from the arc) end of the tube is not to be forced out by the mercury pressure.

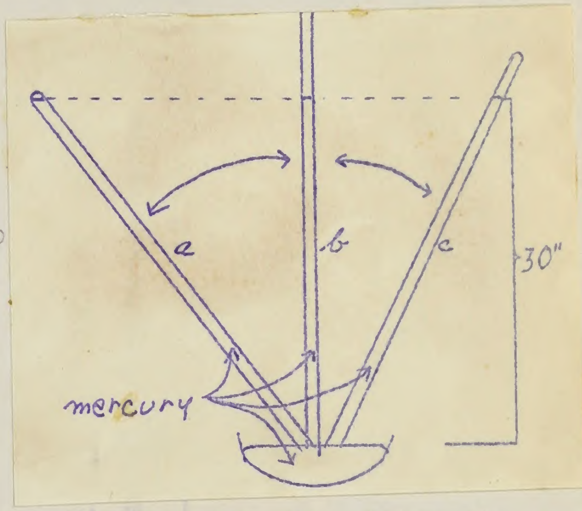


Figure 90. The tube of Torricelli.

3. A similar device is illustrated in Figure 91. This apparatus providing its own bowl eliminates the possible

slip of the thumb which often allows air bubbles to get in and the mercury to be spilled. The apparatus is assembled as shown at the left of the illustration. Simply inverting it puts it into service. Probably, the amount of mercury necessary in this device is less than that needed for the procedure illustrated in Figure 90.

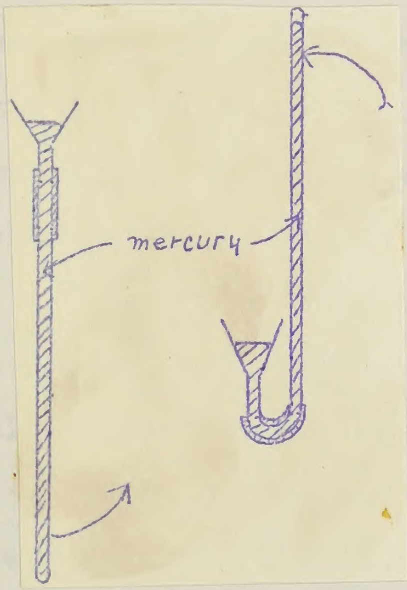


Figure 91. Another Torricellian tube.

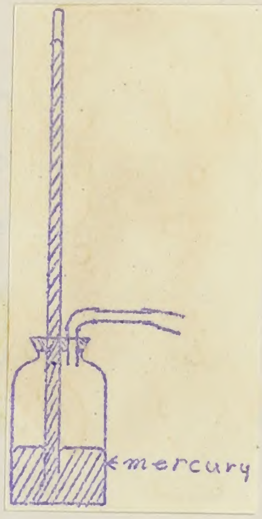


Figure 92. To measure the air or lung pressure.

4. A permanent barometer makes use of a large-mouth bottle, a three-hole stopper, the Torricellian tube, and a rubber hose as shown in Figure 92. The tube is obtained in this position by: Plug it, filled with mercury and right side up, with a stopper. Invert into the bottle and, there, remove the plug.

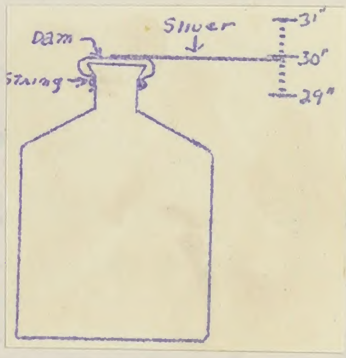


Figure 93. The dry or aneroid barometer.

Mercury is held up by the air pushing in through the open rubber tubing.

To use this device to measure lung pressure, let the mercury of the tube pour back into the bottle, replace the tube in position, close the third port with the end of a pencil, and apply the rubber hose to the lips. Register the force of exhalation by the height to which the mercury is forced. Let two inches of mercury be considered equal to a pound of air pressure. This is inaccurate but the compression of the air will amount to little on the experiment.

5. An aneroid barometer may be constructed with a large bottle, a rubber dam, and a pointer as shown in Figure 93. A scale is supported at the end of the pointer and the scale is adjusted to correspond with the actual pressure measured by the mercurial barometer. The rubber dam may be taken from a discarded bathing cap, or a toy balloon.

Fluid Pressures Abnormal for the Depth
Exert either a Crushing Force Inward or
an Expanding Force Outward
Equally in All Directions.

A. Abnormal pressures resulting from human actions.

1. Any type of container--bottle, tube, retort--is plugged by any means that will leave but one opening. Sucking through a tube in the single hole for the liquid of the flask, is unsuccessful. After opening another port in the stopper, a repetition of the attempt bears results.

2. An ink dropper, the structural basis for the sucking action of the fountain pen, is squeezed by the fingers. If the bladder is released with the jet under water air pressure fills the bladder.

3. Various combinations of results may indicate action of air pressure by use of the apparatus of Figure 94. Here a flask is equipped with a stopper carrying a short and a long tube. Any container that can be plugged so as to provide two ports is satisfactory for use in the experiment. The directions for use are: Blow in at "B" with "A" plugged by the finger; blow in at "A" with "B" plugged; repeat with "A" and "B" open; suck in at "A"; suck in at "B". A convenient wash bottle results if the more deeply projecting tube is equipped at its upper end with a rubber tube and a short glass jet.

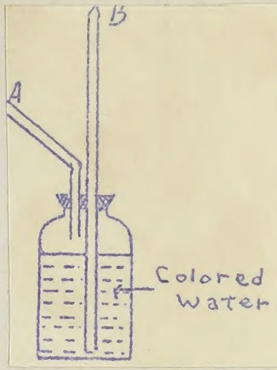


Figure 94. An air pressure device.

4. Inside a gallon jar for which there is a tube-laden one-hole stopper, place two narrow vessels. One of the vessels has its mouth tightly covered with a rubber dam; the other is partly filled with water and is plugged with a stopper carrying a foot-long tube with jet and protruding out of its stopper. When air is sucked from the large container, or forced in at "A", curious observations may be made of air-pressure action. Figure 95 shows the arrangement.

5. Place the wide part of a funnel against the bottom of an empty battery jar or a large glass container, and attach a rubber hose to the funnel's draining end. If, while water is run into the open jar, air pressure is applied to the rubber tube the water will be kept out of the caisson, as illustrated in Figure 96. To hold the caisson down tie weights of lead to the upper narrow part of the funnel.

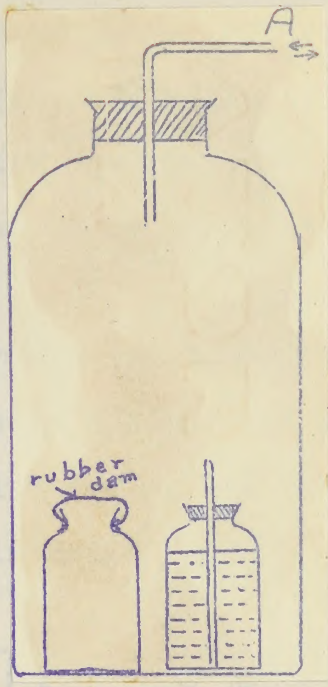


Figure 95. More stunts by air pressure.

6. Place a small bottle at the bottom of a tub of water. Equip the bottle with a stopper, tube, and hose. Replace the water in the device with air by blowing into the bottle through the hose. The in-blown air will provide sufficient buoyancy to lift the bottle and a load that may be tied to it. This shows the principle employed in lifting a ship.

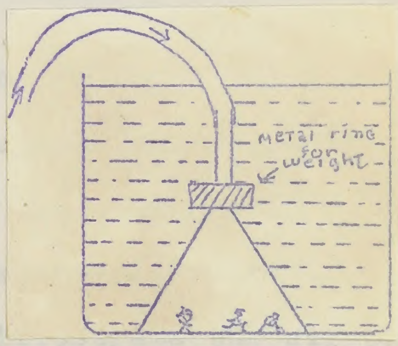


Figure 96. An air-lock caisson.

B. <u>Additional examples of artificial air pressure</u>.

1. A flask or some other container having an opening approximately the size of the diameter of a banana, is partly filled with water which is brought to the boiling

point. After boiling for a length of time sufficient to expel the air in the flask, the opening is plugged with a banana partly skinned. To hasten the action of the condensation of the steam inside the container the belly of it is put under the cold water tap.

2. A great number of pressure-vacuum arrangements are interesting. See Figure 97. In "a" suck out the air and invert into the pan of water. Again, boil water in the flask until the air has been expelled; quickly invert.

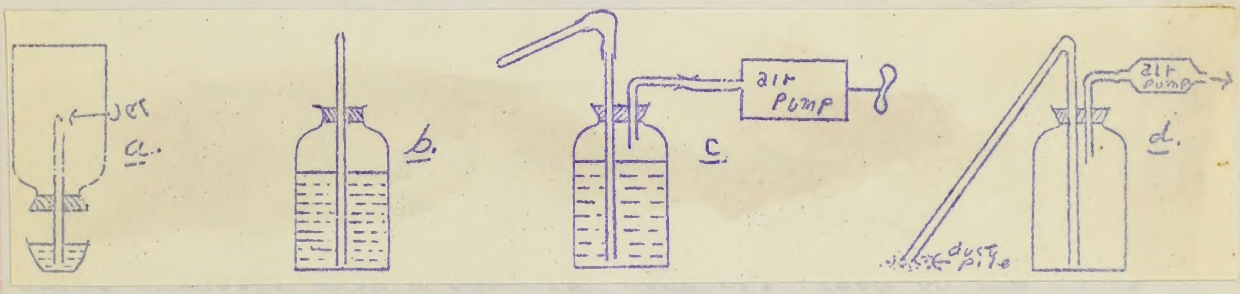


Figure 97. Air pressure at work.

In "b" compress the air at the top of the jar by blowing in or by a pump. In "c" a toy fire extinguisher has a nozzle which can be directed at a small fire. The pressure is high if an air pump operates it and if the escape-jet is small. In "d" suction by a pump or a person will illustrate the air-pressure vacuum principle if the other tube leads to a dust pile.

3. A "perpetual motion" air pressure fountain device is illustrated in Figure 98. A flask equipped with two glass tubes is fastened to a stand. The flask is held in an inverted position with the longer of the tubes protruding into

a tub of water. This long tube has been melted and pulled into the form of a jet, at its upper end, "B". The other tube is only long enough to extend through the stopper and to thereby provide an exit for the water in the flask. As fast as the water drains out of the flask the air pressure becomes sufficiently reduced inside to allow the pressure of the air outside to push the water up the long tube. If the jet of the long tube is small there may be produced a veritable fountain.

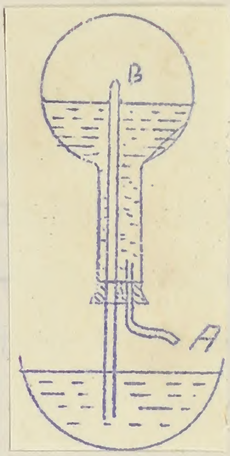


Figure 98. An air pressure fountain.

C. Improvised pumps showing air pressure.

1. Fit a lamp chimney, or any glass cylinder of large diameter with a one-hole stopper. Tack to the inner surface of the stopper a small rubber flap to cover the hole. Protruding from the other side of the hole is a piece of glass tubing. Inside the chimney a cork stopper slightly smaller than the cylinder is held in a movable manner by a dowel rod. This is used as a pump plunger rod. If the glass nozzle is placed under water and the cork stopper pulled away from the rubber stopper the rising of the water up the tube reveals the action of the air pressure in both a lift pump and a force pump. This apparatus becomes a lift pump if a hole is made in the cork stopper and, as with the rubber stopper, a rubber valve, the flap, is tacked over the hole at the top of the cork.

2. The apparatus just described, can very quickly be changed to a force pump. Use a two-hole stopper at the lower end of the cylindrical tube in place of the one-hole stopper. As before, tack a rubber flap over the nozzle entrance for water into the pump cylinder. A glass delivery tube in the other hole leads to a large bottle in an inverted position which likewise is fitted with a two-hole stopper. One of these holes is for the tube from the pump cylinder, the other is an escape tube of the jet type. This inverted jar, thus equipped, provides the air chamber for a continually flowing force pump. Of course, it is necessary to place a valve flap over the upper end of the tube bringing water to the air chamber. As before the piston in the pump cylinders is made by fastening at the end of a dowel rod, a solid stopper which is of such diameter as to readily slip up and down inside the pump cylinder.

Wrapping string around the piston stopper will make it possible to get a close fitting stopper which will move with a minimum of resistance to the sliding motion.

D. <u>Supporting heavier-than-air objects in air</u>.

1. Hold a feather in one hand and a coin in the other; let both objects fall at the same time. Repeat using a thin sheet of paper and the coin as the objects.

Construct a parachute by tying a piece of string to each corner of a handkerchief and fastening the free ends of the

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Constructs a parachute by tying a piece of string to each corner of a handkerchief and fastening the free ends of the

strings to a match stick. Let a match from one hand and the parachute from the other fall at the same time.

Fold a piece of stiff paper in the middle and cut out a glider of the type shown in the right of the illustration of Figure 99. Fasten the creased edges of the glider at the front with a clip.

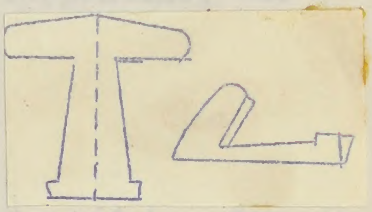

Figure 99. A paper glider.

Allow the paper glider to drop from a height or throw it with an upward thrust and its nose pointed slightly upward.

E. <u>The hydraulic press at work</u>.

1. Secure a press cylinder from the supply room and insert a snug-fitting piston. To the stopcock of the cylinder fasten a funnel by a rubber hose. By pouring in water at the funnel to a level above the piston it will be found possible to lift the weight "W" on the piston.

This same apparatus may be improvised to a certain extent. A large glass jar, like a battery jar, can be pierced to provide the opening for the stopcock. Then a glass tube may be melted or in some other way fastened in the opening as the port for the stopcock. Break off a small piece at the end of a round (commonly known as the "rat-tail") file, Use pliers. This break leaves a sharp edge for the cutting or boring technique. Dip this end into turpentine, and gripping the file near its rough end press gently but firmly into the bottle where a hole is desired. Use a swinging cir-

cular motion. Gradually the scratch will deepen into a hole, and by constantly moistening the tip with turpentine, the particles of glass chipped off will form a grinding paste which helps to bore the hole. Continue the process steadily and patiently although it should not take more than five minutes to go through the glass. When the hole is completed, it can be enlarged to any size by use of the roughened sides of the file. The piston and the platform may be made from a round wooden block wound with string to fit it tightly into the cylinder.

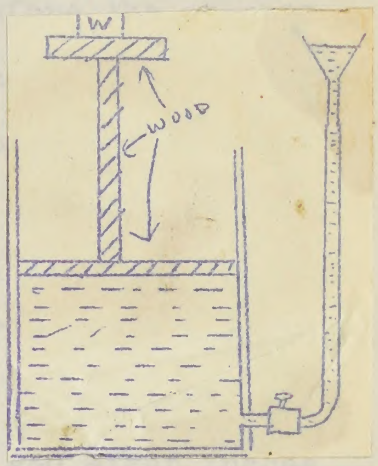

Figure 100. The hydraulic press.

Adding Heat to Fluids Causes Such Increased Activity of the Particles as to Make Noticeable Density Change and Displacement Upward of the Lighter Materials.

A. <u>Circulation of gaseous materials affecting weight</u>.

To show that warm air weighs less than cold, suspend two glass bottles from opposite sides of a balanced meter stick. Add heat to one of these bottles until a noticeable disturbance in the equilibrium occurs.

2. Show that air upon heating expands, by inserting into any empty glass container, a one-hole stopper fitted with a glass delivery tube. This tube, if immersed in water as the container is inverted will reveal expansion of the air trapped inside as heat from the hands, in penetrating the glass

walls, causes the air particles to accelerate in speed. The glass tube is a more sensitive indicator if a drop of colored water is taken into the end of the tube before the stopper and tube are pushed into the glass container.

3. A ventilation box may be improvised in several ways: (1) Turn a wooden chalk box on its side and slide into the grooves a piece of glass cut to the right size. (2) Fasten a fitting piece of glass to the top of a cigar box placed on its side. (3) Construct a pine box of (a suggested size is twelve inches long, eight inches high, and eight inches wide). Spread a thin layer of putty on the edges of the boards, before nailing, to make the joints air-tight. Along the border of the side, which is to be left open, make two grooves so that the glass, cut to fit, will slide up and down. (4) Any tightly bound cardboard box such as a shoe box, fitted with a glass pane one side is a rough substitute but may be used satisfactorily.

Usually, ventilation boxes made of wood are pierced at each end so that there are two rows of holes, an upper and a lower. These holes are fitted with solid materials making it a simple task to plug or open the ports. The glass plate, fastened at the side, allows for observation into the box where are several candles, waxed in an upright position. The candles are kindled, some of the plugs to the holes are removed, and after the glass plate is slidden into place, the

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rate of burning of the candles is the test of the effectiveness of the system of ventilation. In this way, the most satisfactory method may be determined by trial and error experiments with the plugs. The two rows of holes correspond to the top and bottom window sashes of a room. However, this arrangement is unsatisfactory for ventilation boxes made of paper or cardboard because the housing of the experiment would catch fire. Instead, such boxes are usually provided with openings in the roof directly over the flame of the candles, and these holes are fitted with chimneys or glass cylinders which are kept open at both ends.

There are several methods of tracing air currents. First and most common, is the use of the smoke from a piece of rag that has been burning and which is allowed to smolder, only, by blowing out the flame. Joss sticks are often used as also are pieces of punk. A thin smoldering board of a packing box is a good "tracer". A piece of smoking or "touch" paper may be prepared by dipping a piece of filter paper into a solution of potassium or sodium nitrate. When this has been allowed to dry, it, if lighted, will be found to smolder and produce heavy smoke.

4. Unique methods of setting up and tracing air currents in a ventilation box are illustrated in Figure 101a and 101b. One objection to the ordinary candle-ventilation boxes is that the currents are difficult to accurately fol-

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4. Unique methods of setting up and tracing air currents in a ventilation box are illustrated in Figure 101a and 101b. One objection to the ordinary candle-ventilation boxes is that the currents are difficult to accurately fol-

low because of the interfering convection currents set up by the heat of the burning tracer material. The shallow wooden

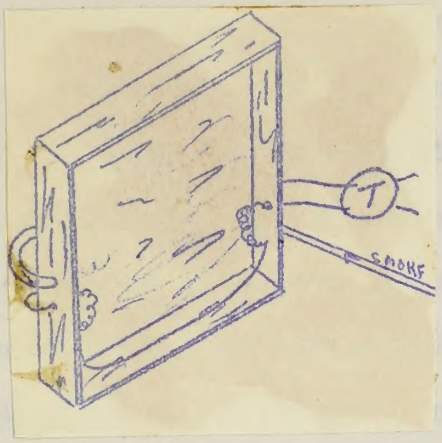


Figure 101a. Ventilation box eliminating the usual interfering air currents.

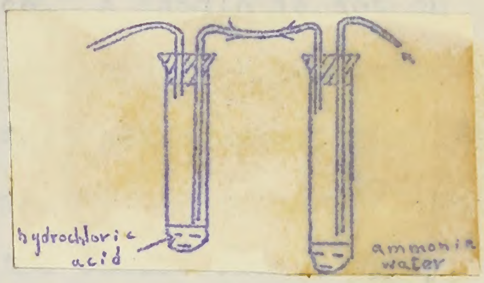


Figure 101b. To make a "tracer" of connection currents.

box in Figure 101a is fitted with a coil of wire at each end of the box. The coils are hooked up with the 110-volt alternating current as cut down by a transformer. The transformer may be dispensed with by hooking a bulb into the circuit and by using small pieces of fine copper wire for the heating coils. Figure 101b explains how "gaseous" ammonium chloride, a white cloudy material, is made. This tracing material is blown into the box as fast as it is made by applying a bellows to the pipe line leading into the box through openings at each end just above the two coils. However, this device is unsatisfactory because of reflections from the glass slide which may interfere with vision into the box. This objection may be minimized by trial and error experiments in placing the box in the various parts of the room.

5. The coldest part of a refrigerator is discovered

either by reasoning or by examining the record of thermometer readings, for which there was exposure to the different shelves for the same length of time.

6. The convection currents around the flame of a kerosene lamp are interesting to trace. A candle is set on a block of wood the width and length of which are less than the diameter of a lamp chimney or a wide glass cylinder is to be placed over the candle. The smaller dimensions of the block allow a circulation of air to the candle flame. Many different arrangements of the materials are possible which help to discover how a candle gets its air supply.

Another of these candle-ventilation procedures follows: The candle is placed on the table, and surrounding it on the table, is a quart milk bottle inverted as a shield on its mouth. Since the bottom had been heat-fractured off, air can reach the flame from above. Holding a piece of cardboard as shown in the illustration the currents of air are easily traced. In the discussion with Figure 29 are directions for the procedure used in preparing a bottom-less bottle. In this case, it is done as near to the bottom of the jar as possible.

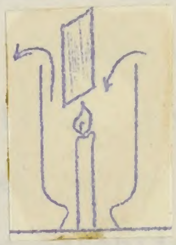


Figure 102. A candle getting its own air.

As a means of determining some of the chemistry of the process of burning it is suggested that a dish of lime-water be placed in with the flame.

B. Circulation of liquid materials because of change of density by heating.

1. A jar of water of any sort is fitted with a one-hole stopper in which is inserted a glass tube. The heating of the liquid in the jar causes a rise in the level of the liquid in the glass tube which thereby acts as an indicator. This shows that the heating of an enclosed fluid apparently causes faster movement of the particles and explains why an increased amount of space is needed. It develops the idea of density change, for as the particles of the heated material speed up, they become more scattered to leave fewer of the particles in the original space.

2. This principle is again brought out in answering the simple question: How does the weight of a volume of cold water compare with the weight of an equal volume of warm or hot water? Two glass containers of equal capacity are counterbalanced on opposite plates of a horn-pan balance, or are suspended from the ends of a meter stick so as to establish a state of equilibrium. If the two containers have a like capacity, fill one with cold and the other with hot water; if they have an unlike capacity, measure out equal portions of hot and cold water for each. The loss of balance by the meter stick will indicate the answer to the question.

Convection currents in fluids are traced by "tracer" materials such as carmine, potassium permanganate, ink, copper sulphate, nitrate crystals, bits of graphite (lead pencil),

and bits of saw-dust. Carmine, potassium permanganate, and the graphite filings are recommended.

3. Place a small amount of the tracer material in a flask partly filled with water. Heat the water gradually and note the currents as revealed by the tracer.

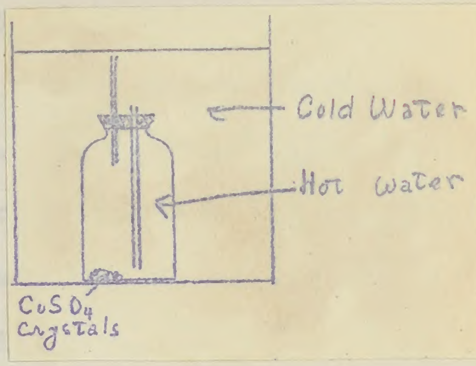


Figure 103. Liquid convection currents.

4. Figure 103 shows a simple way of tracing the convection currents in liquids. A battery jar of cold tap water completely inundates a smaller container filled with hot water and outfitted as shown. In addition to the two glass tubes, one long extending to the

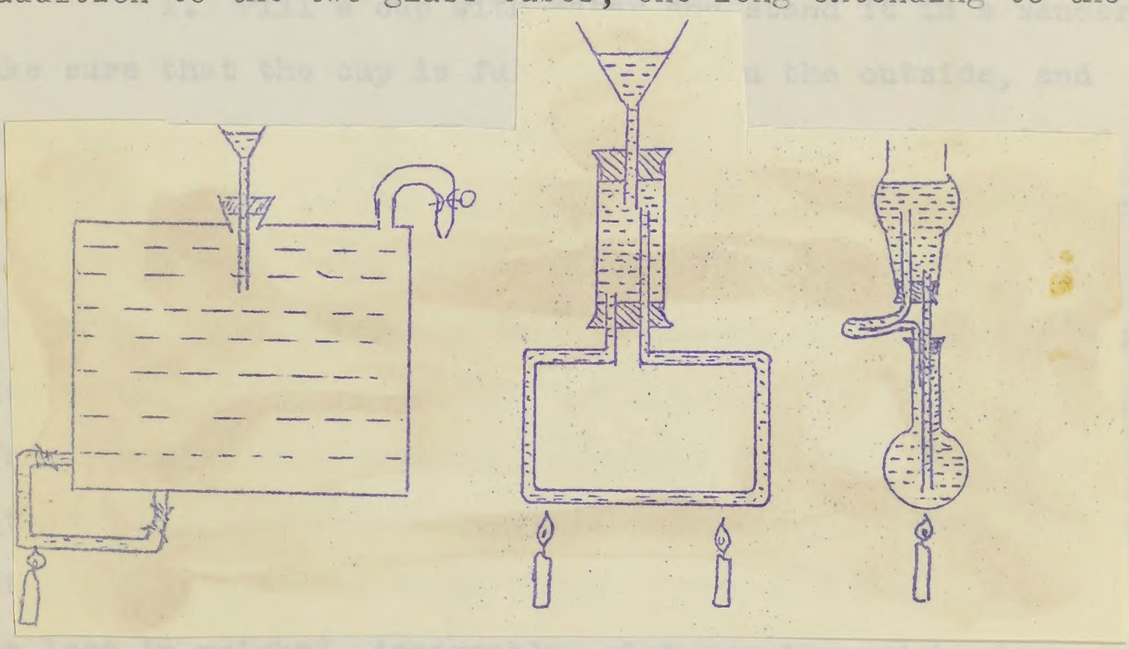


Figure 104. Hot water heating models.

bottom of the container and the other, short, extending from the stopper an inch or two, there have been placed at the bottom of the inside of the small container a few crystals of

tracer material.

5. In Figure 104, a variety of hot-water heating models is indicated. The circulating fluid should be preheated to boiling to drive off dissolved air. If a thick glass container is used heating of it should occur through the thickness of an asbestos padding. Tracer crystals may be necessary if observations must be taken from any distance.

Floating Bodies Are Displaced upward until the Weight of the Fluid which They Displace Equals Their Weight

A. The weight of the water displaced by a floating body equals the weight of the body.

1. Fill a cup with water and stand it in a saucer. Make sure that the cup is full and wet on the outside, and that the saucer is dry. Float as large a block of varnished wood as possible in the cup. Weigh the water which runs over into the saucer. Wipe the block dry and weigh it.

With a spring balance weigh a wooden block. Fill a cup with water, and as above, set the cup in a large dry vessel, a saucer the weight of which is known. Let the block sink into the vessel of water until it floats alone. What does the water in the overflow vessel weigh? What was the amount of the loss in weight? Apparently, what was the weight loss of the block?

2. A stick of the dimensions shown in Figure 105 is fashioned on a lathe. A small hole is bored in one end

which is used as a depository for materials with which to bring its weight up to 250 grams. The stick is marked off at one-centimeter intervals for 30 of its 40-centimeter length. It is then suspended in a tub of water dangling from the hook of a spring balance with its "graduated" end down. Observations of the weight of the stick, as registered by the balance, are made at each of the intervals on the stick. If the stick is 9 square centimeters in cross section, a loss of 45 grams of weight for each five-centimeter drop of the stick should be noted. Water pushes against the immersed part with a force of 90 grams as it sinks to the ten-centimeter level, and the scales show a weight of 160 grams. At the 25-centimeter mark the scales register a weight of 25 grams, a loss of 225 grams due to the buoyant force of the 225 cubic centimeters of water which have been displaced by the stick.

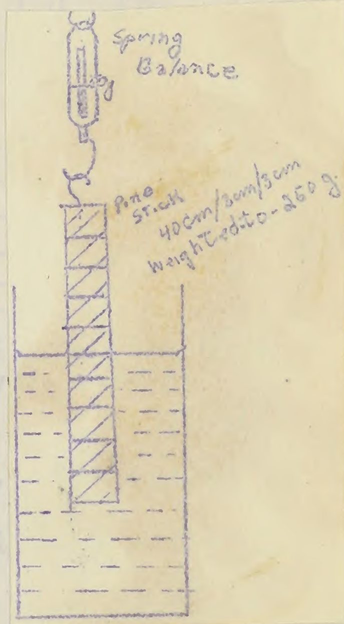


Figure 105. Weight of liquid displaced equals the loss in weight.

3. Three sticks are cut to the same length and cross-sectional area, that is, 30 centimeters and one square centimeter, respectively. They are weighted in the same order to 24, 30, and 36 grams. Strips of lead, nails, thumb tacks, or an incision of mercury are suggested for the ballast. The first is found to have buoyancy in liquids of 0.8 specific

gravity; the second in liquids of 1.0 specific gravity; and the third in liquids of 1.2 specific gravity. Figure 106 illustrates the sticks and the degree of buoyancy in water.

4. A piece of tin foil from a candy or gum wrapper is folded to make a little boat. It is observed to float in water and then, after being crushed into a wad, it is observed to sink.

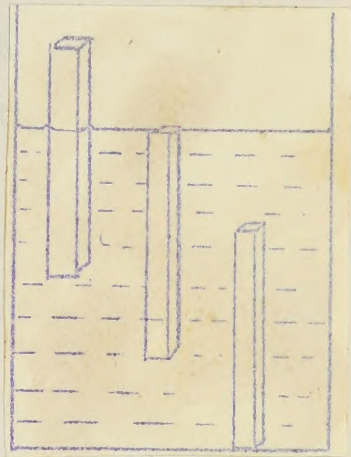


Figure 106. Liquid hydrometers.

B. <u>Cartesian</u> <u>divers</u>.

1. A small common bottle is filled with water, and a tiny vial about one-half filled with water is immersed inverted in the larger container. The bottle is fitted with a cork stopper and the vial has liquid added to it or withdrawn from it until it floats with none of itself out of water. The flat of the hand or a sheet of paper is placed over the jar; as the paper or hand is pushed in the diver sinks. He recovers if the pressure is relieved.

2. Mayonnaise or cheese jars with air-tight covers prove equally effective in a battery jar for which rubber damming provides a cover. The buoyancy of the smaller jar is adjustable by the amount of water contained.

A small bottle with its contents adjusted to buoyancy is immersed into the water held by a larger container. This larger bottle is covered over with a piece of rubber dam. The

dam may be supply-house material or it may have come from a discarded bathing cap, a toy balloon, or inner tubing. In the absence of rubber damming, the bottle may be fitted with a rubber stopper carrying a glass and rubber delivery tube. To operate the diver, either push in on the dam or squeeze the rubber tube.

4. A carved wooden man is loaded with tacks at the bottom, until buoyancy in water is reached. This makes a diver.

5. A wooden cylinder is wound with six or eight turns of bared copper wire one end of which is held to the cylinder's base by the stem of a thumb tack. If the stick has been weighted to near buoyancy, it can easily be adjusted to that condition shortening or lengthening the copper wire.

All permanent blocks made of wood should be paraffin treated to prevent water absorption.

6. A large test tube, as shown in Figure 107, is fitted with a one-hole stopper carrying a fine tube closed at one end, this protruding. Hence, this tube opens into the test tube. Approximate buoyancy, due to a weighting with lead shot, can be adjusted to sensitive buoyancy by a push or pull on the fine closed tube fitted into the stopper.

Figure 107. A tube for specific gravity.

C. <u>Simple problems of buoyancy shown</u>.

1. Make a chart of the air pressure, air tem-

perature, and hygrometric (relative humidity) readings for a long period of time. To deduct a relationship between air pressure and relative humidity, make comparisons of these two during the periods of similar air-temperature observations. An understanding of the fact that there is a change in the specific gravity of the air as its water vapor content changes, should result.

2. Prepare a bottle of hydrogen and one of carbon dioxide. Place the bottle of hydrogen right side up under an open tumbler for a minute. After a few seconds bring match flames, simultaneously, to the mouth of each container. Keeping the carbon dioxide in its container by a cardboard laid across the mouth of the container, place it upside down over a similar bottle in which a candle is burning. Quickly remove the card. These experiments provide experience with gases having a specific gravity less than or more than that of air.

3. The fact that an egg loses moisture as it remains exposed to the air suggests a way of testing for the relative freshness. Immerse several eggs, some old and some fresh, marked accordingly in lead pencil, into a bucket of water. Examine them in a dark room, with a candling box as shown in Figure 108. What is the significance of the trans-

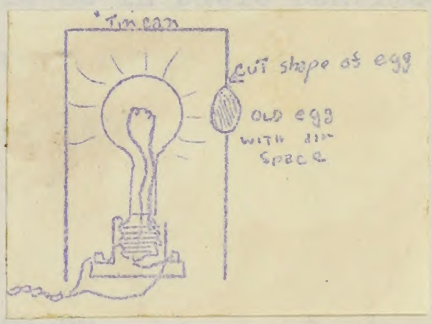


Figure 108. A candling box.

lucent area at the top of the eggs that do not sink? Should fresh eggs sink or float? Why?

Objects Heavier than the Fluids in which They Are Immersed Lose Weight Equal to the Amount of the Displaced Fluid.

A. Buoyancy specifically.

1. Take any small weight (heavier than water) such as a piece of lead, a glass stopper, or an iron weight, and attach it to the hook of a spring balance by means of a fine string, or fine bare wire. The object's weight is observed. Then the object is immersed slowly (so as to cause little slopping) into a water-filled vessel which is equipped with an overflow rubber tube leading to a graduated cylinder. The type of graduate depends on the readings of the spring balance; if it is in pounds or ounces, the graduate should be in ounces; if it is in grams, the graduate should be in cubic centimeters. To graduate a cylinder in ounces; pour a pound (453.6 cubic centimeters) of water into a large regular cylinder and note the approximate level with the eye, as likewise, the level for two pounds of water. These are indicated at "A" and "B", respectively, as of Figure 109. Between these two marks anyway, make a matt surface of the glass upon which the graduations may be stenciled or pencil

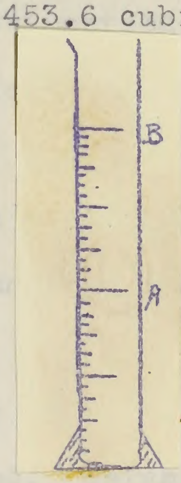


Figure 109. A large self-graduated cylinder.

marked. For this process use a corundum hone, and after attaining the needed degree of roughness, relocate the two points, "A" and "B", more accurately and mark with a pencil line. Now divide this area into 16 equal parts. As the object becomes immersed, observations on this new scale will reveal the weight of the volume of the water displaced in ounces. This reading will be found to correspond with the loss in weight of the object as indicated in the spring-balance scale. If many readings are desired, on this ounce scale, heavier objects should be used. This brings out the truth of the principle of partial as well as that for total immersion.

This graduate may apply for other fluids, if two or more ounce scales are added, for example, one for alcohol, and one for turpentine. By this it is possible to find relative densities of floating bodies. The body, floating, displaces its own weight in water, and when totally immersed, an equal volume (the weight of which is available on the scale) of liquid.

2. Cast a block of cement one foot on a side. Get its weight in air (about 150 pounds) and then find its weight when suspended in water.

3. Fill a test tube having a capacity of 30 to 40 cubic centimeters about one-third full of sand. Weigh and adjust the total weight of tube and sand to 30 grams.

Fill a large graduate to within 35 or 40 centimeters of its volume from the top. Float the tube of sand in the water and notice how much water is displaced.

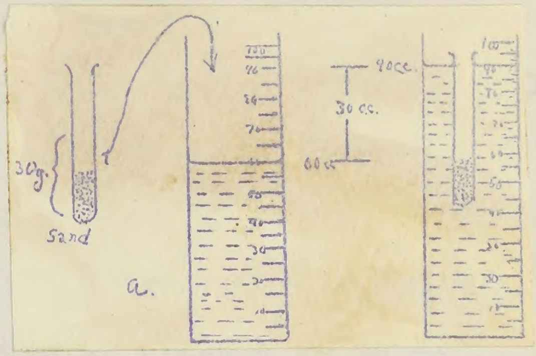


Figure 110. To take accurate buoyancy measurements.

B. <u>Buoyancy in general</u>.

1. As in Figure 111, inflate the balloon from the lungs, by applying the lips at the part indicated by the arrow head. The balloon expands to displace more water. As the upthrust increases the balloon rises. Allow the air to escape at the arrow head and notice how the balloon loses buoyancy accordingly. Set up a similar apparatus using a balloon of the same size, but loaded with a heavier weight.

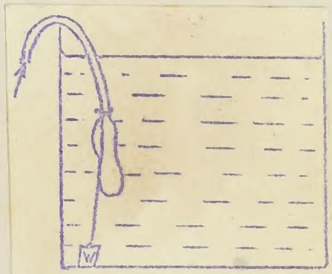


Figure 111. Lifting sunken objects.

C. <u>Inertia of motion</u>.

1. Any two round balls, one heavy and the other light, but similar in size and smoothness of surface, or any two toys on wheels in which the friction qualities are approximately the same, are obtained. Allow each, in turn, to run down the same incline starting from a standstill, and measure the run in each case. Compare the distance covered by the light roller with that covered by the heavy roller.

2. Again, a light and a heavy wheel are given approximately equal rotary impulses. The time of continued motion is noted with a watch. It is suggested that the small wooden wheels of a cart, and the heavier metallic wheels of a tricycle might be found at a junk heap.

3. A piece of cork and one of metal of size having about the same weight, are suspended by strings of equal lengths. In starting them in pendulum motion they are given equal arcs through which to swing. Make comparisons of the length of time for the continued motion of each.

4. Inertia of motion is also illustrated by simple gyroscopes. Notice Figures 112 and 113. A "tin" disk, four or five inches in diameter, is cut from a flat tin dish, or from a food can. It is suspended from a string attached to a button through a hole in the center of the disk. If the disk is given a circular motion it flops around irregularly. If the disk is first given a rapid spin and then swung in a circle, it will spin, as it swings, in a plane parallel to the original plane of the spinning motion.

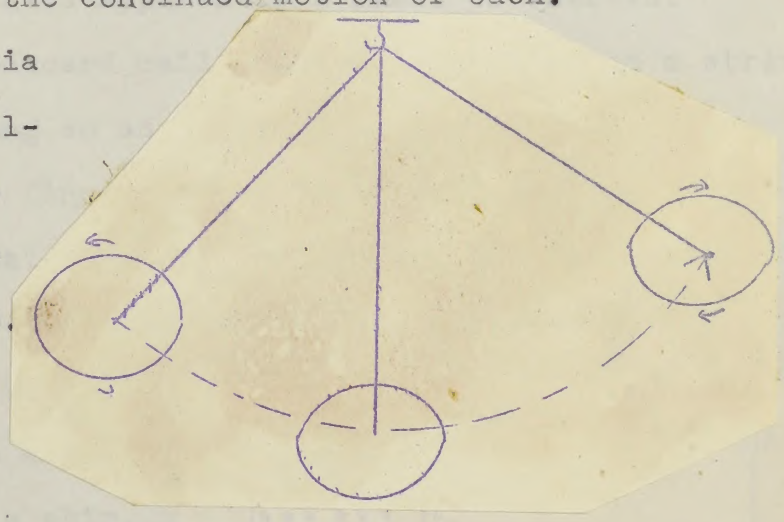


Figure 112. Motion of a gyroscope.

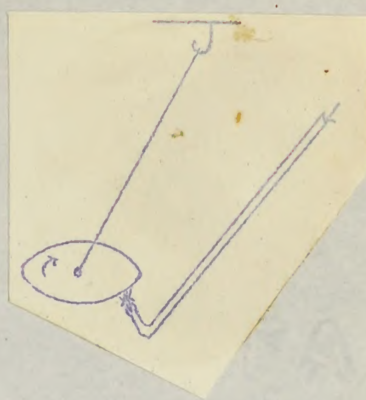


Figure 113. Again the gyroscope.

Now eliminate the swinging motion and renew the spinning. As it now spins send a blast of air delivered from the mouth through a rubber tube at one edge of the spinner. Instead of upsetting its inertia to induce the wobbly motion the blast merely causes the whole apparatus to climb to a self-adjusted, angular position. This illustrates the obstinacy of the gyroscopic motion, which is apparently a phase of inertia.

5. A cardboard mailing tube, suspended on a string five or six feet long so as to swing on its long axis, is given a <u>spin</u> by the fingers and a swing with the hand. Its curved path, not that expected, brings out the principle of the rotor ship, or of the curved path of a baseball.

6. In a shop it is not difficult to model a cross section of a ship, balanced by a pendulum, as shown in Figure 114. A toy gyroscope is mounted so that by a string in the hands, it can be tilted in the fore and aft direction. Set the ship to rocking in its

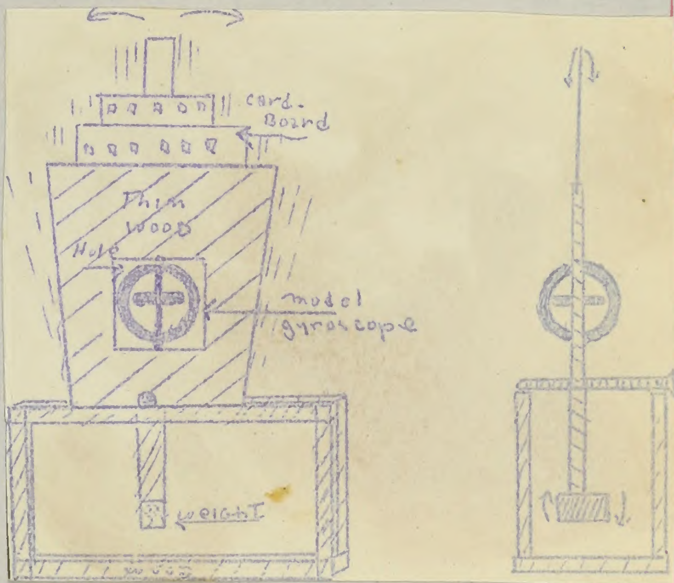


Figure 114. The ship's gyroscope.

cradle. Then by pulling the strings to and fro in the proper rhythm with the roll of the ship, steadiness is added to the entire mass. The gyroscope must be under control or its motion becomes that of the ship's motion.

7. Place a ball at the back of a low box with an open end. Move the box in the hands in any horizontal direction with the open end ahead. Stop the box suddenly and note the ball's continued motion. Instead, roll a ball away from you and give it reverse "English" as it stops; its continued rotation may bring it right back to you.

8. One experiment, with no promise of validity, involves letting a watch make of itself a pendulum. Suspend a time-keeper by a long string, set it in a weak pendulum motion, and note first the retarding influence of the internal vibrations which stop the pendulum. Soon afterward, note that the internal vibrations have caused a resumption of the motion.

9. Remember that the inertia of motion is that which so commonly is used to tighten the head of hammers and axes on the handles.

A Body Impelled by
a Constant Force Has
Uniform Accelerated Motion.

1. Any two similar balls are used. One is given a forward motion along the table top, and the other is dropped from the edge of the table, simultaneously.

2. As shown in Figure 115, blow a marble from a horizontal glass tube. As it leaves the tube, a wire is brushed aside to break an electromagnet circuit. This lets the iron ball become a freely falling body. At the same time the ball which was blown from the tube became a freely falling body with horizontal impetus. If the glass tube is level and at the same height as the ball under the electromagnet, and if the tube is carefully aimed, not only can the two balls be seen to fall together, but also it is possible to get them to collide in mid-air.

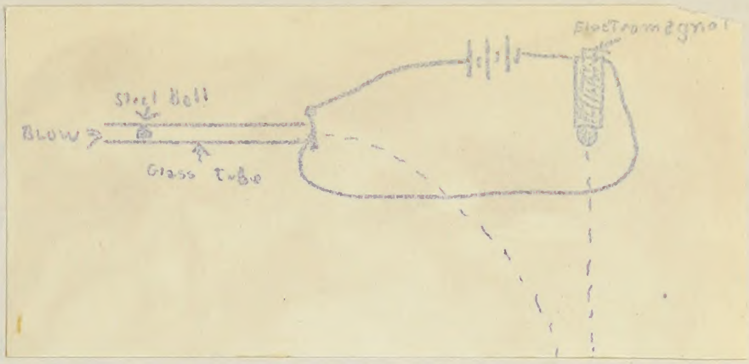


Figure 115. A body falling freely.

3. In Figure 116 it is essential to have two metallic balls, one of which must be of magnetic substance. Ball bearings are often used in this set up. The ball at the right is purposely chosen to act not only as a roller but also to complete the circuit of the electromagnet part of which includes the two metallic bars and the roller on them. When this ball leaves the shoot, it breaks the electromagnet circuit to release the ball in the illustration

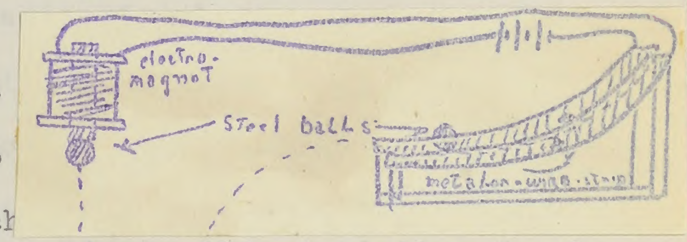


Figure 116. A similar freely falling body.

at the left. If the height from which the roller ball is released, is varied, different combinations of the interaction of the inertia of the two balls result. Both balls have the pull of gravity from which the freely falling velocity is obtained, and the ball at the right has, in addition, its inertia in a horizontal direction.

Liquids in Connected
Columns of Water Flow
toward the Greater
Gravitational Attraction.

1. A single curious example of the structure of a siphon is illustrated in Figure 117. Fit a jar, open at the two ends, with a one-hole stopper carrying a circular glass tubing. When liquid in the siphon jar begins to flow through the tube gravitational attraction for the length of liquid in the projecting tube causes a flow in that direction, air pressure can cause it to continue until the jar is emptied. Years ago this was caused the "Tantalus Cup".

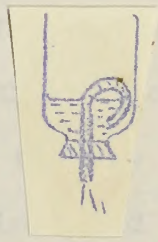


Figure 117. The "Tantalus" Cup.

A Natural Force
of Some Materials
Is Magnatism

Good permanent magnets may be found in a country telehone box, and in any discarded generator.

A. Making magnets.

In addition to the methods of making magnets which were

described in Chapter II, concerned with the transforming of electrical energy to magnetism, there are the usual methods involving the use of magnets with magnetic substances. A few of these procedures are described below.

1. Rub one end of a sewing needle (any other thin piece of steel such as a straightened watch or clock spring, or a steel knitting needle, or a file will do) with the "north" of a magnet, then rub the other end of the needle with the south of the magnet. The rubbing should be done with a semi-circular motion beginning by contact between magnet and needle at the middle of the needle. The magnet, maintaining contact, moves toward and beyond the end of the needle, and returns to the beginning again by the way of a circular route. Repeat the process several times, and reverse it for the opposite ends of the needle and magnet. The needle is now magnetized. Keep strong magnets away from it while the testing of its magnetism is in process. The testing methods are described in part B, below.

2. Break a triangular horseshoe or bar magnet in half. The steel of these is brittle, so that a heavy hammer may provide the necessary impulse. After testing these halves, and finding that each half is now a magnet, put them together again at the fracture, and find that they again act like a single magnet. Take one of the halves, break it into quarters. Test each quarter.

3. Find a nail showing no indications of having been magnetized. See if it will pick up a tack, or iron filings, or cause a compass needle to change its direction. Pick the nail up by one end with a permanent magnet and with the nail dangling, test its magnetic powers by dipping into a mass of iron filings or other small materials of iron or steel. This induced magnetism, likewise may be shown by using other iron materials instead of the nail, that is tacks, a spike, horseshoe, parts of a discarded transformer, screw, nut, washer, paper clip, piece of "tin", thumb-tack, needle, pin, pen-point, and so on. These materials will respond in different degrees. Understanding of this is instructive because it is useful in the development of understandings concerned with electromagnets. Further testing should be done with these materials after the strong permanent magnet is removed to show the different degrees of retention of the magnetic properties.

4. Hold or clamp a long iron bar into a near horizontal position in a north-south plane with the end nearer the north pointing about 45 degrees downward. Set a compass just beyond the range of any magnetism which the bar has, before dipping the bar into this inclined position. With a hammer gently tap the end of the bar several times after adjusting the bar to the inclined position described above. Observation of the compass needle should indicate that the

earth's field of force has influenced the bar.

5. A curious method of making a magnet is: Twist a small strip of metal into the form of a cylinder like a paper mailing tube. The ends of the metal strip should show magnetic powers. Such pieces of twisted metal can be found in the waste material of a carpenter metal-worker.

B. <u>Testing magnets</u>.

1. To formulate the nature of the magnetic field of a magnet place the object to be tested flat on the table. Using small props cover the object with a piece of stiff paper or glass, sprinkle iron filings on the cover, and gently tap it with the end of a pencil.

2. Cover a magnet with iron filings. Then lift the magnet and shake it to see where the center of the magnetic power is located.

3. Hold two magnets with unlike poles facing each other close enough to make apparent the attraction between the unlike poles. The repulsion of the like poles for each other can not as definitely be perceived with weak magnets.

4. The idea of the mutual reulsion by the like poles is made apparent in one of the following ways:

One magnet is suspended in a vertical position in the air. A second magnet is moved up in the same vertical plane and is held so that there will result, unless some adjustment of the suspended magnet occurs, the meeting of the like poles of the two. Just before this would occur the suspen-

ded magnet moves out of the way.

A second way of getting at the repulsion of the like poles for each other is obtained as shown in Figure 118. In this experiment two magnetized needles are suspended by cotton threads sufficiently far apart as to have no apparent effect upon the vertical dangling position of each other. One end of a bar magnet is so placed as to cause the tip of one of the needles to move toward the bar, and the tip of the other needle to climb out of the way. This second needle demonstrates repulsion.

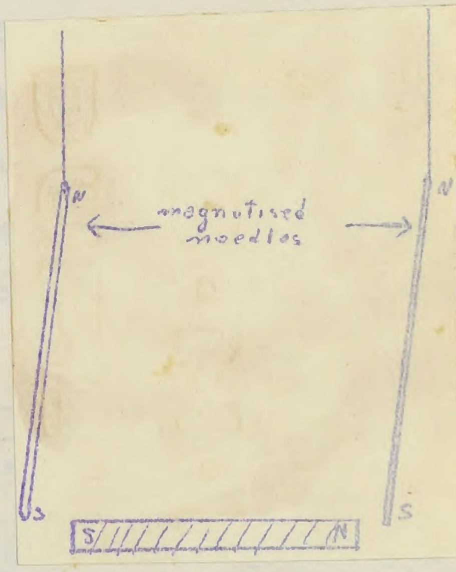


Figure 118. Like poles repel.

A bar magnet is suspended from a hook by means of a cotton thread, tied around near the ends of the magnet, as shown in Figure 119. A second magnet is brought up to that suspended in such a way that like "north" poles approach each other. A second trial brings the like "south" poles toward each other.

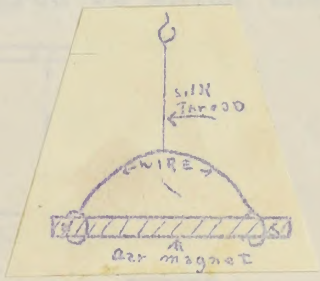


Figure 119. A compass.

It is interesting to dip one set of the like poles of two magnets into iron filings, to get a heavy bushy load at each of the like poles. Bring these two loads toward each

others' paths. This is more impressive if now the unlike poles, loaded with the filings, are brought up to each other. Entirely different results of a convincing nature, may be brought to light as shown in Figure 120. Two bar magnets, on the bench, are covered with a stiff paper. Iron filings are poured on this cover paper; it is tapped. The magnetic fields reveal the law of magnetic poles.

5. Numerous methods are suggested by which a magnet becomes a compass. The main problem is that of suspending the magnet with such delicacy as to make the resistance in the cord which the magnet has to overcome in adjusting itself to the earth's magnetic field, a negligible factor.

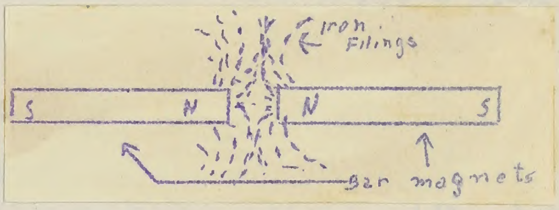


Figure 120. Unlike pole repulsion.

The suspension of Figure 119 can be made with sensitivity in the degree to which the two wires can be brough close to each other.

In Figure 121, the magnetized needle should protrude through the piece of tissue paper. Another method makes use of one of these magnetized needles sticking through the upper part of a cork floating in water. Again as in Chapter II, the spinner for the electric motor, in which a cork

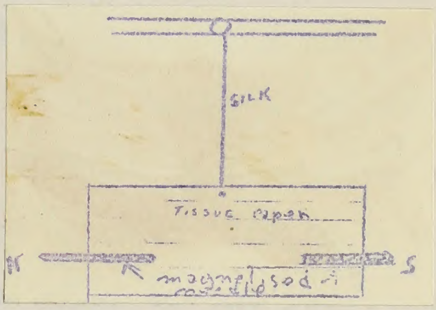


Figure 121. The magnetized needle.

pivots on a glass tube supported on the tip of a nail, can be used as the sensitive spinner for a compass. Or, a floating cork can become the turn-table for a magnetized razor blade or watch spring.

6. One suggestion for making a dipping needle uses as a pivot axle a straight fine wire stick through a tiny cork and resting on a smooth hard support. The "dipper" is a magnetized steel knitting needle piercing the cork at right anles to the direction of the pivot wire. This wire must be fine, yet, it must have resistance enough to remain straight in spite of the bending force of the weight of the needle.

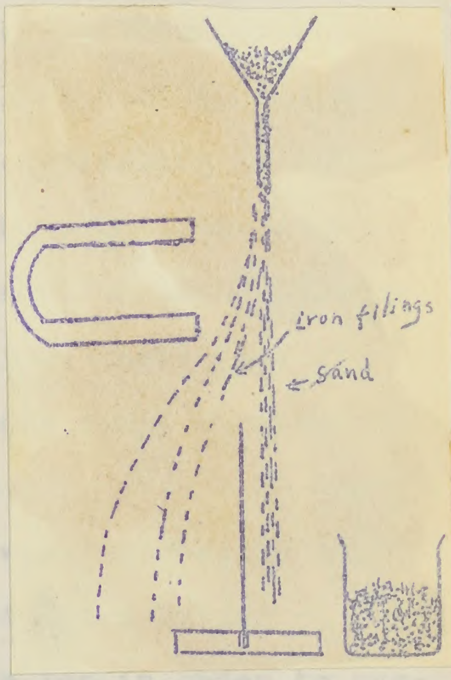


Figure 122. The magnetic separator.

7. A curiosity is the "magnetic" separator which is illustrated in Figure 122. As shown, allow a mixture of fine dry sand and of powdery iron filings to drop from a funnel across the poles of a permanent magnet. The iron filings and the sand separate the opposite sides of the partition.

Apparently,
All Material Is
Electrical in Nature.

A. Showing electrical attraction and repulsion.

Unfortunately, experiments in static electriciy are often

begun in hot weather, when for some reason, perhaps that greater quantities of water vapor are in the air, the materials of the statics experiments are discharged to the atmosphere at a fast rate at the expense of inferior experimental results. People can observe that electrical storms are more frequent in hot weather, but this observation is insufficient to justify the explanation of the relatively poor results in statics. Instead, this explanation sound like an alibi for ignorance. Fortunately, however, there is a simple experiment which makes possible a more ready acceptance of that explanation.

1. Attach to any model of a water-reservoir equipped delivery tube. Elevate the reservoir to a height of several feet, and feed the tank from the tap in order to provide water at pressure which will push the water out in an arc of several feet before dropping into the sink. See Figure 123. An overflow or a steam boiler and a rubber hose, or any large container with a siphon, may make the reservoir and delivery pipe. The tube is a fine glass jet used in order

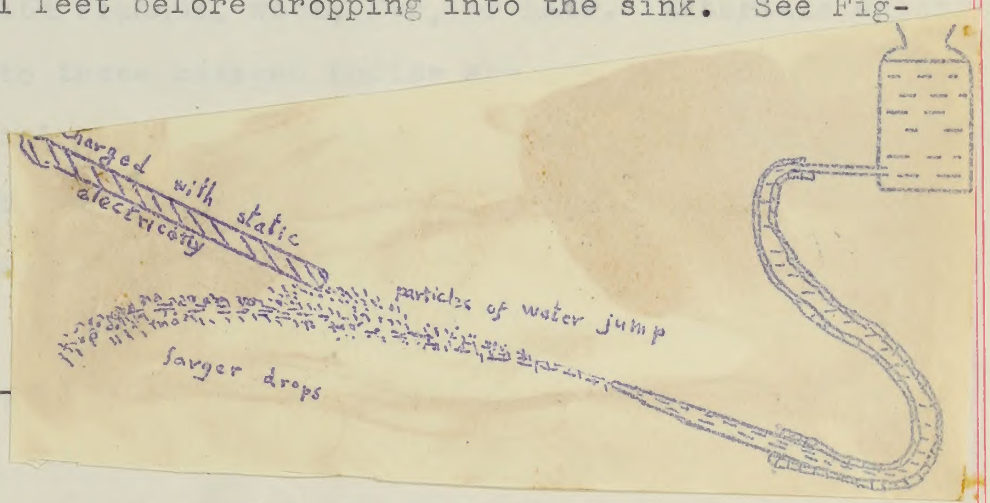


Figure 123. A static attraction for small drops of water.

that the water will escape in a stream of finely divided drops. A piece of amber, hard rubber, or a comb may be charged by a brisk rubbing with a piece of fur, the hair, or wool, and is quickly brought to a position about an inch or two above the height of the spurting arc. Two things of interest happen. The drops of water jump out of their usual arc, strike the amber, rebound, and then combine to form larger drops of water. Descriptions of methods for charging common materials with static electricity are: Rub a roll of newspaper in the folds of an overcoat armpit. Rub a fountain pen, a non-metallic comb, a piece of sealing wax, a resinous material, or a piece of smooth wood in contact with flannel, wool, fur, or hair. Rub a piece of glass tubing, solid or hollow, or a glass bottle or plate in contact with silk. Run a rubber comb through a cat's or dog's fur. Rub an inflated toy balloon with flannel, wool, fur, or hair. Materials which will respond to these charged bodies are any dry, finely-divided materials, as for instance, bits of paper, cork, pith, hair, feathers, tinfoil, or whole ping-pong balls or inflated basketball bladders.

1. To show that the nature of these charged bodies is electrical, take any one of them to a radiator, or water faucet, where close observation will witness a small spark jump between the charged body and the grounded material.

B. Simple electroscopes.

1. A pin, supported as shown in Figure 124, sup-

ports bits of cork as pendulums at the ends of silk thread. A charged body approaches them. Attraction between the charged body and the cork is noticeable. Without letting the charged body be touched take it to a water faucet or radiator to note the discharge of electricity to the grounded object. The snap of the spark can be heard, and the tiny flash may be seen.

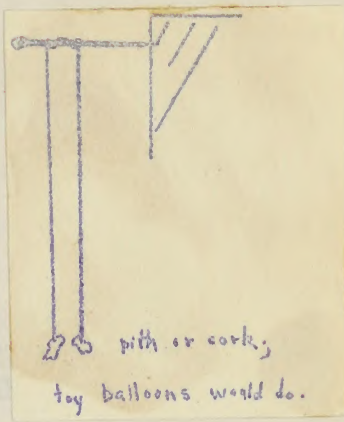


Figure 124. Simple electroscope.

2. Scuffle across a rug and hold the knuckles near the ground or a piece of metal held by another person.

3. Whittle a cork in a bottle to a point, and balance a silver spoon on the point. A well charged body can cause the spoon to revolve.

4. Suspend two balloons, two ping-pong balls, two pith balls, or two bits of cork from the same support by dry silk so that the two objects are just touching. Bring near a charged body. Let the two suspended balls touch the charge, and then note their mutual repulsion.

5. The glass plate, referred to, is laid on insulating supports half an inch from above a sheet of metal on the bench. Bits of paper or cork are placed under the glass plate. The plate is rubbed vigorously on its upper surface by a piece of silk, and the bits of pith jump back and forth to show their charging from the plate and discharging to the metal.

CHAPTER IV

PHYSICAL AND CHEMICAL CHANGES INVOLVE APPEARANCE, PROPERTIES, AND COMPOSITION OF MATTER

Oxidation Takes Several Forms and Requires Certain Conditions in the Surroundings.

A. Each material requires a definite temperature in order to oxidize with a flame.

1. A flame goes out if its heat is carried away too fast. This may be a method of preventing the flame from spreading. We see indications of this in the laboratory when we place a wire gauze over a flame to protect materials from uneven heating. The flame burns but not above the heat-conducting gauze. Sir Humphrey Davy demonstrated that this idea when applied could prevent explosions of coal dust and mine gases--thus the Davy Safety Lamp. Several simple experiments bring out this application:

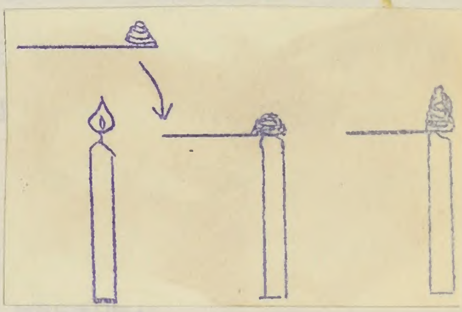


Figure 125. Putting out a flame by heat conductor.

2. Bend a copper wire into the shape of a pyramidal cone at least a half an inch in height and of a suf-

ficient diameter to slip over and completely cover a candle flame. If the cone is used as shown at the left and center of the illustration in Figure 125, the candle flame is extinguished. If, however, the coil is preheated to red heat and then used as in the above, the flame of the candle is not effected.

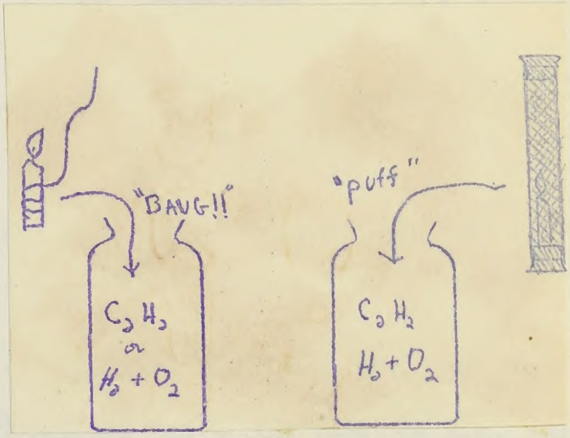


Figure 126. The Davy lamp principle.

To bring out the Davy application: Take a bottle of hydrogen or acetylene and insert first a burning candle on a drop wire, and second, a burning candle surrounded by a wire cage. As illustration 126 shows, insertion of the unprotected candle gives rise to a sharp explosion, and the insertion of the cage causes a "Puff!" as the candle goes out but no explosion is heard. Make the wire cage by wrapping a narrow two-inch strip of copper screening around two corks in which the edges of the screen should be caused to interlock. Caution: Do not open the gas bottle until you are ready to test with the flaming candles, because the gas will quickly escape.

3. The principle of the "strike anywhere" and of the "safety" match is the same as that underlying the use of the different materials commonly used to kindle a coal fire. There are several slightly different procedures for this idea.

First, compare the kindling temperature of a splinter of wood with that of a lump of sulphur as shown in Figure 127. Pour melted lead in between the materials on the asbestos pad at the left of the diagram. Since lead melts at 330 degrees Centigrade, this method has the advantage of giving a definite known temperature of sufficient magnitude to cause one of the substances and not the other, to take fire.

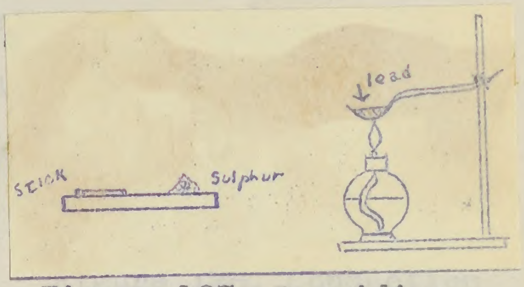


Figure 127. Providing a known kindling temperature

Again, place a tiny piece of yellow phosphorus, using forceps to avoid touching the phosphorous with the hands, on a metallic pan and apply heat under the pan. Then compare the readiness-to-ignite of other substances such as bits of paper, wood, paraffin, or sulphur with each other by pouring out on the same pan a line of sulphur powder from the phosphorus to each of the other substances to be tested.

Third, place in one circle on an asbestos pad, supported by a ring stand, bits of phosphorus, sulphur, charcoal, splints, coal bits, and paraffin. If the flame of the heat source in use is hot enough, apply it until even the coal is smoking. Other methods call for the use of a piece of fine wire gauze as the support, or a sheet of metal with small circles, one for each of the materials, each equidistant from the spot of application of the flame.

4. A simple procedure which makes possible a better understanding of the use of wooden utensils which can be exposed directly to flames is illustrated in Figure 128. Shape any bit of paper into the form of a shallow basin, or fold a piece of filter paper into the usual funnel shape. Fill the paper container partially with water, and support it by holding it with the fingers, if necessary, over a direct flame. The paper will be found to remain intact even though it chars slightly. Meanwhile, the water comes to a boil and remains boiling for several minutes. In connection with this, mention the use of bark utensils by the early American Indian.

Figure 128. Conduction preventing the paper dish from burning.

5. When a material oxidizing without a flame is surrounded by insulating materials, the heat accumulates to make possible the firing of the material. Such spontaneous combustion experiments are suggested making use of two similar methods. First, dip a piece of cotton strip, four inches by two feet long in a readily oxidizing fluid, and hang it on an iron support in the room. Make the oxidizing solution by dissolving a few grams of yellow phosphorus in 50 cubic centimeters of carbon disulphide. The cloth should never be handled with the hands--use iron tongs, or even a long pair of scissors.

Second, make up to 40 cubic centimeters a mixture of equal parts of gasoline and carbon disulphide. Dissolve two grams of yellow phosphorus in this. A handful of wool waste or cotton batting is placed (away from combustible materials) in a deep iron pan on the bottom and sides of which is a layer of absorbent insulating paper such as cardboard. Filter the liquid into the waste and cover the waste with paper for insulation. A siphon is suggested as the means of transferring the fluid because it then is unnecessary to touch the fluid, and also because it cuts contact with the air to a minimum.

B. <u>All flames are burning gases</u>.

Make careful examination of the nature of a flame to determine where it is hottest, to see where no actual burning occurs, to relight a "blown-out" flame without touching its material source, and to carry some of the gas away from the flame and there light it. A candle flame will prove satisfactory in all cases. The procedures follow:

1. Match heads are stuck into the center and splints are inserted into a flame, horizontally, to find the places in the flame where no burning occurs and where the burning seems most concentrated. The match heads can be held in the actual central cone, without ignition, for a longer time than in the side,

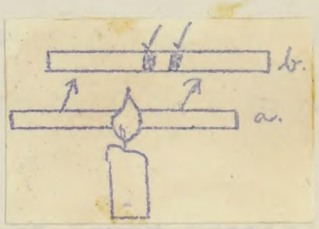
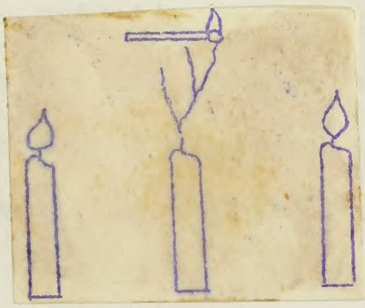


Figure 129. Where burning occurs.

tip, or base. Several splints, held for a moment as indicated in Figure 129 at "a", show charred areas of greater extent at the points of contact with the edge of the flame as shown. Removing the stick to position "b", less blackening of the wood in contact with the flame's central cone is observed. If a piece of paper is held in the hands in a horizontal position above a flame and is lowered until in the same part of the flame as the splint at "a" above similar observations may be made.



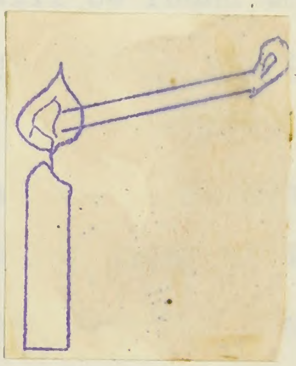


Figure 130 Figure 131
Cases showing a flame as a burning gas.

2. There is some invisible substance which continues to be produced even after the flame goes out. Show this by reigniting the candle without bringing the fire-source directly in contact with the wick. The ease and place of this reignition indicates that a flame might very well be a burning gas. See Figure 130.

3. In Figure 131, ignition will be found possible by touching a lighted match to the upper end of the glass tube. To avoid clogging of the tube by the condensation of the vapor it is necessary to heat the tube before attempting use in this

manner. Especially is this to be observed because where is but a small amount of the vapor at any moment in the candle flame the glass tubing should be of small bore, at least to the extent of a "jet" tip.

This experiment is quite convincing if a syringe is at hand. Insert the tip of the syringe into the central cone of the flame, and slowly suck the gas found there into the cylinder. Then bring a burning match to the tip of the syringe and blow out its contents. They too will be found to burn.

C. Oxidation of any type requires certain conditions.

Many simple procedures will show that something in the air is necessary for any type of oxidation. A suggestion concerned with the logical (author's opinion) order of instruction is to work out the action of oxygen ahead of time after use of any one of several ways of preparing the gas: (1) Decompose mercuric oxide or potassium or sodium chlorate (when mixed with manganese dioxide) by heating. (2) Decompose sodium peroxide in water. (3) Electrolytically decompose water.

1. That air is necessary for oxidation is shown by many different methods. As in Figure 132, a burning candle covered over by a deep dish is found to be easily extinguished.

A unique way to keep a candle oxidizing is represented in Figure 133. This is especially good if it accompanies observation of the results of the next experiment.

A small bottle holds an erect, burning candle as in Fig-

ure 134. A series of steps indicated by the succession of sketches explains the story of the procedure. The candle, held erect by means of a wire, is lowered into the jar and a glass plate is moved across the top of the jar to shut off the air. After the candle is extinguished the jar is carefully inverted into a tub of water. Loosening the glass plate from the jar top, water, by moving up into the jar, indicates the use by the candle for something

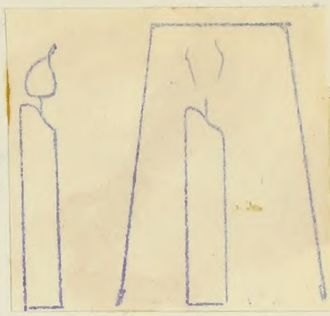


Figure 132. To cut off air from a flame.

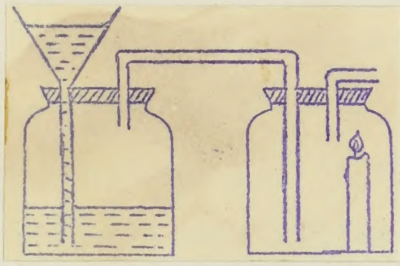


Figure 133. Providing the necessary air.

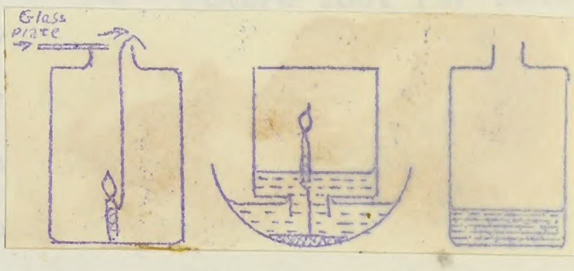


Figure 134. Burning something in the air.

in the air as it burns. Then the glass plate is again used to block up the jar, and in this manner, the water sucked in is trapped. This water can be measured and the quantity compared to the actual capacity of the jar. Measurements can be made afterward or a paper scale can be prepared beforehand and stuck to the wall of the bottle. In either way, the percentage of oxygen in air can easily be computed.

Tightly clamp on the top of a mason jar in which a candle is burning. The candle, of course, soon suffocates itself and and in so doing uses oxygen from the air to reduce the air

pressure inside. When the gas inside has cooled, the mason jar is opened in an inverted position with its mouth under water. Exactly the same procedure is followed as in the preceeding method to determine the percentage of oxygen in the air.

Perhaps the most common procedure is illustrated in Figure 135. Place a small piece of phosphorus in a tin foil dish, and on top of a pan of water float a small candle on a cork. Then place the dish with the phosphorus on the hot water near the burning candle.

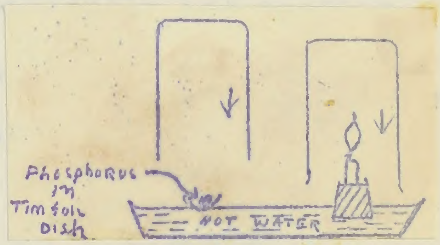


Figure 135. Per cent of oxygen in air.

The phosphorus should begin to burn almost immediately. Using tumblers of cylindrical shape invert one over each of the floats of oxidizing materials and clamp the tumblers to the bottom of the pan to prevent the escape of gas expanding as a result of the heat application. As the flame is extinguished the water gradually is pushed up into the tumbler. The percentage of oxygen in air can then be estimated.

2. Similar experiments but of slower action bring out the value of linseed oil in paint, and also, the apparent necessity of moisture, in addition to oxygen, to hasten certain examples of oxidation. In the first case, a wad of filter paper is soaked with boiled linseed oil, and, used as a long plug, is pushed through to the bottom of a test tube. The

whole is then inserted into a shallow dish of water so that the mouth of the test tube is immersed. Indications of oxidation will be apparent after several days. The experiment explains the use of linseed oil in forming an oxidized covering wherever this oil is a necessary constituent of paint.

Second, moisten a test tube on the inside so that iron filings will adhere. The moisture, apparently has another purpose, too. The tube, open-end down, is dipped, into a jar of water, and left for a day or two. In this amount of time the oxidation change, commonly known as rusting, will have occurred. As a control, dry iron filings are placed similarly in a dish floating on water, and the tumbler experiments are compared.

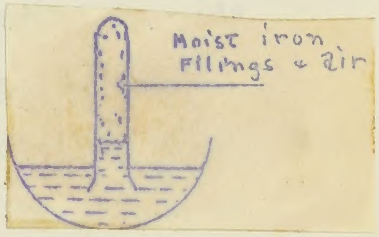


Figure 136. Rusting as oxidation.

3. A mixture of carbon dioxide and oxygen is collected by the water displacement method. The jar is filled to about one-fifth of its volume with oxygen and the remainder is filled with carbon dioxide. When a candle is inserted, it will be found that the candle burns in much the same manner as in ordinary air. This shows that carbon dioxide does not directly affect the respiration value of the air.

4. Oxidation, we are told, is the union of oxygen with a fuel. Since both the oxygen and the fuel are forms of matter an increase in weight might be anticipated. Two tin covers with magnesium powder in one and sand in the other are threaded, suspended and then balanced on a meter stick. The

magnesium in its counterbalanced position is heated only until burning begins. As burning progresses, answer the question: Is the apparent difference shown in Figure 137 entirely due to an increase in the weight of the material burned?

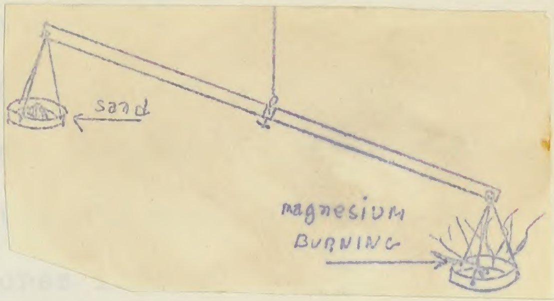


Figure 137. Showing weight gain as a result of burning.

D. Removal of any necessities of oxidation.

The process used most commonly is the cutting of the air supply. This is accomplished mechanically, by carbon dioxide, of its effect upon a fire, of its specific gravity and of its sources; and second, in the case of carbon tetrachloride, of its specific gravity. As preliminary experiments to bring out these prerequisite ideas about carbon dioxide follow any of these procedures: (1) To show the sources of carbon dioxide, pour an inorganic acid or vinegar into a soda solution, and upon limestone, in each case testing the gas by passing it through lime water. (2) To show the effect of carbon dioxide on combustion, collect a jar of the gas, stand it covered on the bench and uncover it just in time to allow a match or burning splint to be inserted. (3) Specific gravity is shown as follows: Take one bottle of the gas and "pour" it into a similar size bottle of air. Then find out where the carbon dioxide is by inserting a match or burning splint into each bottle. A procedure, similar in purpose, is illustrated in

Figure 138a. After holding the vessels in each position for a minute, both are set upon the bench, and tested for carbon dioxide as directly above. In one case the splint continues to burn; in the other it immediately is extinguished. The actual fire extinguishing procedures follow:

1. Fold a cardboard, as in Figure 138b, in the form of a funnel or drain and fasten a series of candles to the inside bottom of the trough. The candles are lighted, and a bottle of carbon dioxide, with a paper cover is poured down the trough.

2. A solution of soda water is made by disolving baking (or washing) soda in water in a wide-mouth bottle. Vinegar is poured into the jar and immediately, a burning match is plunged into the opening. Better still, the set up of Figure 139, is used satisfactorily. Stick a candle in an erect position to the bottom of a mason jar and entirely surround the candle's base with soda water. Carefully funnel the vinegar so that it does not drop on the flame. The effect of carbon dioxide on the combustion is quickly noticed if sufficient reaction occurs between the vinegar and soda. It may be difficult, however, to get good results

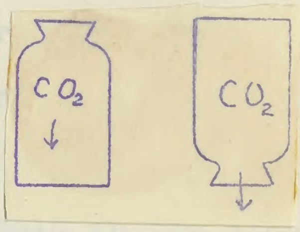


Figure 138a. To compare weights of carbon dioxide and air.

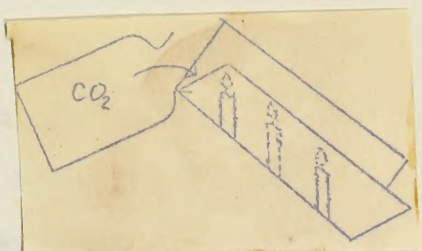


Figure 138b. To compare weights of carbon dioxide and air.

if the bottle mouth is so wide, and the candle so tall that neither the carbon dioxide evolved nor the bottle exit can cut off the convection current which the flame sets up.

3. A more realistic apparatus imitates the construction of the old-fashioned soda acid extinguishers. This is a most common device and is easily put together. Take a large bottle plugged by a one-hole stopper which fitted with a rubber and glass jet delivery tube. Fasten a small vial to the interior of the large bottle by a wire in the rubber or cork plug--as shown in Figure 140. A dilute solution of soda water half fills the bottle and the small vial, is filled with dilute sulfuric acid. A jet is attached to the end of the rubber tube and this, held by one hand, is directed at a fire in a galvanized iron tub, while the other hand inverts the bottle and applies as much pressure as possible with which to hold in the stopper firmly.

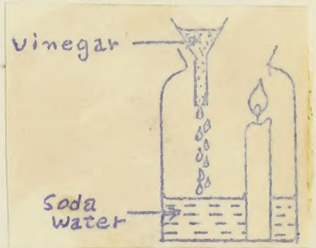


Figure 139. To replace the air necessary to the oxidation.

3. Another realistic extinguishing method is common. Throw a mixture of sand and soda at the base of a small fire and note the result.

4. A lard fire is easily begun and if not too serious, is easily extinguished. Melt a heap of lard in a soup ladle, touch a match to its surface and experiment with extinguishers. Pour some water onto it. The fire continues as

badly as before. When a wet cloth is thrown over the top of the ladle, the fire goes out.

5. Water is likewise proved ineffectual on a gasoline fire in a flat pan. The wet cloth proves satisfactory. Again, relight the fire and add a few drops of carbon tetrachloride. This is very effective.

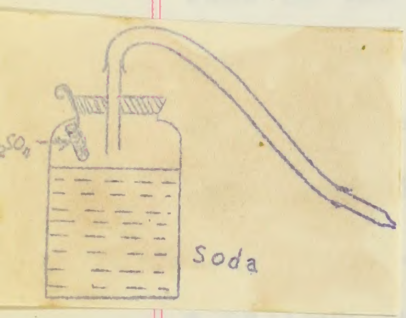


Figure 140. An extinguisher.

We Recognize Materials by Their Physical and Chemical Properties.

A. <u>Invisible materials nevertheless real</u>.

There are numerous simple procedures to suggest that air occupies space. The problem of the elasticity of air--its reality--are the ideas involved.

1. The usual procedure is very simple. Any glass vessel is thrust open end down into water, note is taken of the height to which liquid in the vessel rises by comparing it with the depth of insertion. A small piece of cork easily seen through the glass wall is used as a tracer.

Figure 141 illustrates a second common procedure. This process is varied by lifting the stopper momentarily. Note

that the water in the funnel is no longer held up. As a variation of this, place the funnel in one hole of a two-hole stopper, and leave the other hole to be blocked or opened by the thumb at will.

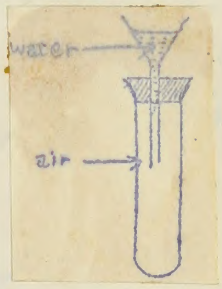


Figure 141. Air taking space.

2. Into the cylinder of Figure 142 nearly filled with water, a long glass tube on the upper end of which a toy balloon is fastened, is inserted. Since the balloon is seen to puff out as the tube goes deeper, it must have been filled with air, a real substance apparently.

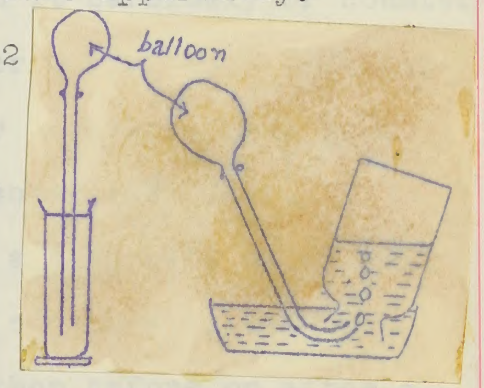


Figure 142. The reality of air.

3. At the right in Figure 142 a balloon is twice filled with air in successive parts of the experiment. In the first part the balloon is inflated by the mouth and with a delivery tube this trapped air is caused to escape into a gallon jar, as shown. In the second part, a pump, attached to the balloon, is used to force indirectly a much greater quantity of air into the jar.

4. To prove that the "unreal" air has a definite weight reality use the inflation possibilities of various containers: bladders of basketballs, soccer-balls, rubber balls, toy balloons. Tie one of these to one end of a bar and after it is evenly balanced inflate it from the mouth or by an air pump (preferably). Hold the bladder carefully in place, and

pierce it to let out the air. As the air under pressure leaves, a considerable amount of weight apparently is lost.

5. In Figure 143, the flask containing some water, is heated till it boils. Keep applying the heat until it is probable that most of the air has been forced out. Then just as the stop-cock "A", on the rubber connection of the delivery tube is closed, the flask is removed. When it is finally cooled weigh it carefully or counterbalance it on the end of a pivoted meter stick, then open the stop cock. The action of the scales or counterbalance indicates the effect of allowing air to enter the flask.

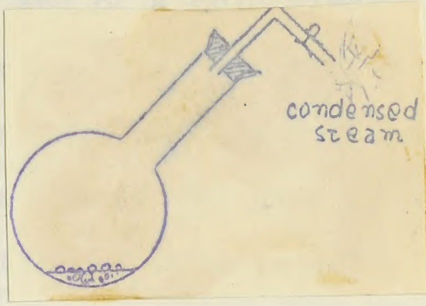


Figure 143. To expel air.

6. A hollow steel ball with a stop cock or an old electric light may also be used. Each of these is weighed and counterbalanced, the steel ball either before or after a load of air is compressed and the electric light bulb before piercing. Afterwards it is "cracked" to let air in. The cracking of the incandescent bulb is a simple task illustrated in Figure 144.

First, though, the bulb is counterbalanced with a pan of sand. Then a jet is made by pulling out a piece of glass tubing and cutting off the end.

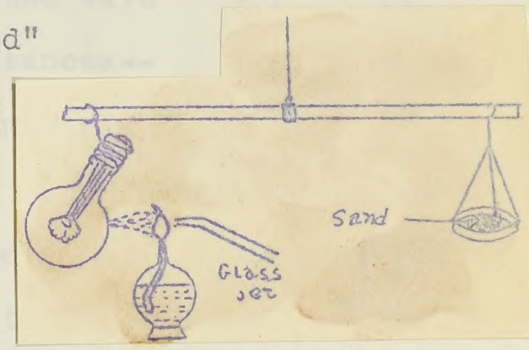


Figure 144. Preparing to find weight of air.

The jet is used as shown to direct a tiny hot flame at the bulb. After a spot is well heated, the end of a cold piece of iron is touched to the spot, or a drop of water is placed there. In this latter method of cracking the bulb, a similar drop is then placed in the pan. Observation of the balancing stick will, if an old so-called vacuum type of bulb is used, indicate the increase of weight due to the inrush of air.

B. Chemical changes due to heat.

The vast number of experiments pertaining to the heat-chemical change relationship would provide a nearly inexhaustible source of material. In studying the origin of carbon dioxide the source of fuel gas and simple metallurgical processes the idea is developed. Experiments follow:

1. Figure 145 illustrates the meaning of the word "unstable" as applied to the permanence of composition of a soda solution. Use lime water as a test for carbon dioxide to bring out one of the ways and means of identification of substances--dependence upon the solubility of one material for another.

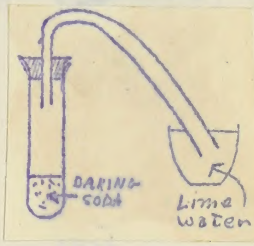


Figure 145. Heating the baking powder.

2. The next two experiments give meaning to the expression "organic materials are unstable if heated". Distil in a clay pipe capped with plaster of Paris (calcium sulphate) a charge of organic matter to produce a combustible mass of gasses. The plaster cap is easily dug out afterwards to make

possible the examination of the residue. Plaster of Paris may be puttied over the pipe bowl as often as desired to provide a high-temperature bake cap.

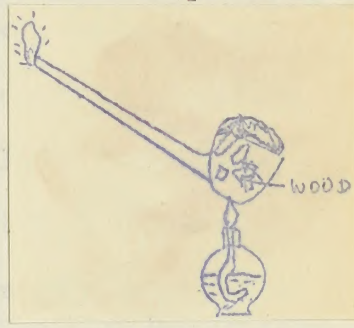


Figure 146. A clay pipe distilling.

In Figure 147, the material used to charge the retort is paper while the generator is a hard glass test tube (a short length of copper or iron piping is serviceable but, lacking transparency, is inferior to hard glass). A tin can, in an inverted position, and having two holes punched and fitted with glass tube jets, when inserted in a tub of water provides a means of mimicking the "gas works" storage tanks. The can, if weighted on top, is more realistic. The delivery tube of the tank penetrates a large piece of cork bored and outfitted to represent the Bunsen burner. A stop cock on the rubber delivery tube from the tank is missing from the diagram. Likewise, the model of

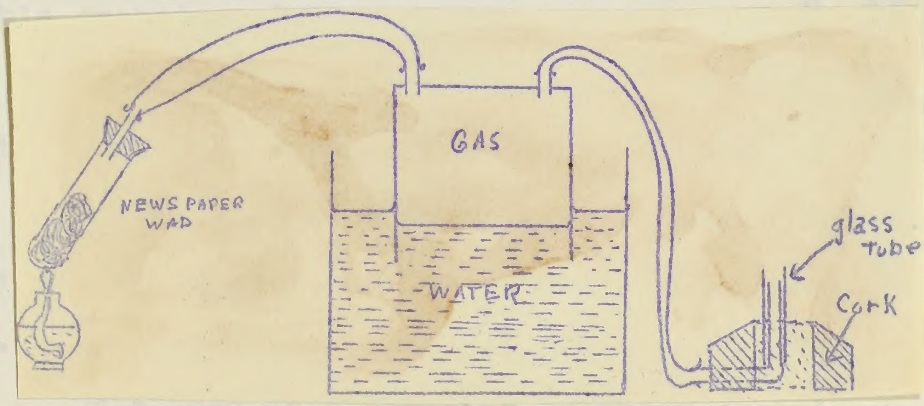


Figure 147. Preparation storage and use of gas.

the Bunsen burner may be more simply contrived than the diagram indicates. Merely connect the rubber delivery tube to

the lower end of a glass tube sticking down through the cork itself held up an inch or two from the bench by small blocks.

3. The metallurgical use of carbon and heat as reducing agents to cause the metals of the ores to give up their oxygen or carbon dioxide and thus be left uncombined, is shown with powdered coal and one of the three oxides, mercuric, lead, or copper. Figure 148 shows the mixture of powdered coal and the mineral oxide as suggested above. White lead, the carbonate, always obtainable at the paint shop, will provide a fourth common mineral. The proportions (by weight) should be as follows: mercuric or lead oxide, 18 parts, to one of coal; copper oxide, 5 parts, to one of coal; and white lead, 22 parts to one of coal. These combinations on an asbestos pad over a hot flame will produce the reduction. In the case of the mercuric oxide, however, the mercury would be missing were this procedure followed, because of the low boiling point of this metal. For this reason the mercuric oxide is heated in a test tube or other closed retort, and later found in tiny silver beads along its cooler inside.areas.

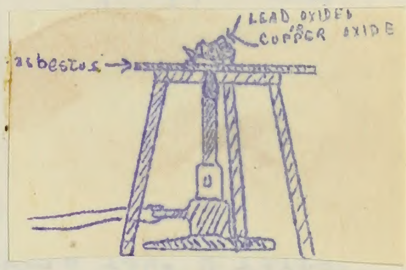


Figure 148. Reduction.

C. Chemical action, not oxidation, and resultant heat.

This idea is a familiar everyday experience to many people: (1) the garage boy in diluting the strong sulphuric acid for the storage battery; (2) the mason-worker's son in slaking the lime for mixing plaster; (3) the house girl in

"cutting" the grease of the drain pipe, by the "Drano" or lye treatment. The idea may be extended further as a result of the observation of the action of strong lye on a piece of aluminum ware or zinc.

D. <u>Materials</u>, <u>non-oxidizing</u>, <u>as</u> <u>fireproofing</u>.

A strip of paper may be made fireproof by soaking it in one of the following three solutions. First, sodium or potassium stannate, at a specific gravity of 1.22. Second, ammonium sulphate, specific gravity, 1.75. Third, a concentrated solution of zinc chloride.

E. <u>Degree</u> <u>of</u> <u>solubility</u> <u>a</u> <u>means</u> <u>of</u> <u>separating</u> <u>substances</u>.

1. The process of water purification, by filtering, applies this principle in extracting the soluble materials. Puch a tin coffee can through the bottom by a nail and plug the hole by a nail or tack of lesser diameter which will therefore fit loosely. Figure 149 illustrates the requirements pertaining to the nature of the layers of sand and gravel.

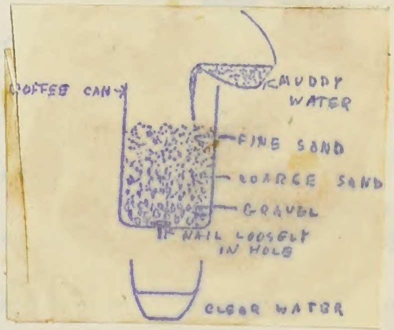


Figure 149. A filter bed.

2. A lamp chimney, as seen in Figure 150, illustrates the successive layers of gravel, coarse, and fine sand necessary to the make-up of a good filter bed. Almost any fine woven cloth tied over the open neck of the chimney holds in the rock material.

3. Some old chicken bones may be thoroughly dried out by continued roasting in a crucible. These are crushed to small bits after a few hours of strong heat, and mixed with some commercial bone black. This mixture makes an effective filtering material as shown in Figure 151. It takes out of solution even some materials that are dissolved. Thus, sugar and syrups in solution are absent as a result of thorough filtering in this device.

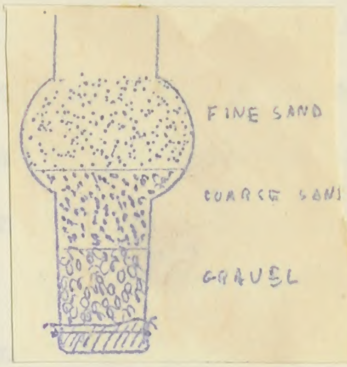


Figure 150. The lamp chimney as a filter.

4. One of the alum salts, dissolved in water, takes sediment out of muddy water.

Figure 151. The boneblack filter.

5. That air is dissolved in both water and soil is easily brought out in a number of ways. Reference to the experience of the cold tap water, which in a warm room becomes all "bubbly" on the inside of the container, is a good beginning to the problem of air solubility in water. Reference to the bubbles formed during the preliminary heating process of a pan of water is a second common experience. Heat a glass or test tube of water for the repetition of this experience.

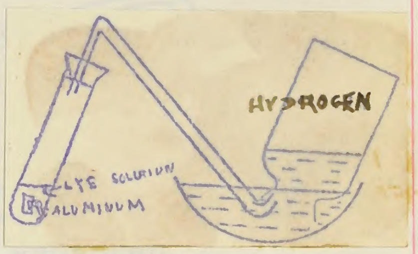


Figure 152. Making hydrogen at home.

F. <u>Unusual preparations</u>.

1. Hydrogen is made by the action of aluminum in

strong lye, caustic soda, or potash. Zinc in a hot solution of these materials will likewise bring out in a way the making of hydrogen at home. Lye is more common than acids. A third method is the use of sodium acid sulphate with hot iron nails.

2. The experiment illustrated in Figure 153 is infrequently used, because it is not as easy as it looks. The soapy water should be comparatively cool and the viscosity of the suds should be high. The quality of the soap and the hardness of the water are pertinent factors. By experimentation with different soap types, the proper consistency can be secured.

3. Baking soda and vinegar or fruit juices are the materials for preparing carbon dioxide.

4. A handy piece of improvised apparatus is the Kipp generator substitute. Figure 154 illustrates materials necessary to the making of hydrogen sulphide gas. The necessary materials for the preparation of many gases will work well in this apparatus. A large glass cylinder is fitted with a one-hole stopper in which a glass tube is placed. The tube, equipped on its outer extension with a rubber hose and stopcock arrangement, penetrates the one-hole stopper of a smaller

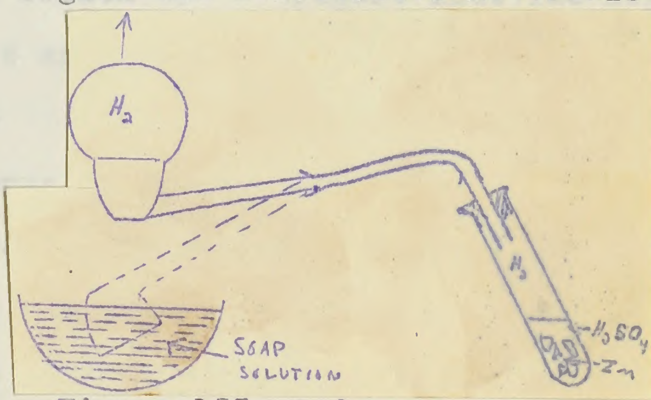


Figure 153. Hydrogen filling soap bubbles.

cylinder acting as the "solids" container--in this case powdered iron sulphide. This small cylinder has its other, lower end plugged with a single-hole stopper carrying a small glass tube which acts as an inlet for the reacting liquid--hydrochloric acid. In its operation the pressure of the gas generated keeps out the reacting liquid if the clamp at the outlet is closed. When the clamp is open, the reacting liquid finds its level by working up into the inside cylinder.

The iron sulphide is easily made by setting fire to a mixture of two volumes of powdered sulphur and one volume of iron filings on an asbestos pad or metal sheet. The material can be broken up by a hammer pounding against an iron block.

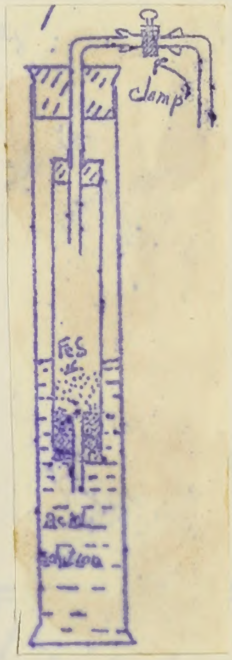


Figure 154. The Kipp generator substitute.

Action of Forms of Energy upon
Matter Causes Change in
the Volume of the Matter

A. Tension in solids.

1. The apparatus in Figure 155 illustrates the effect of a stretching force upon the form of a wire. Any material in wire form may be tested in this manner. The particular wire being tested is hooked to the ceiling so that in hanging its perpendicular line extends downward close to the

bench. A long splinter of wood which extends across the level of the bench. It just touches a tiny block on the bench, This splinter acts in the capacity of a pointer, the end at the left moving downward as the wire is stretched, the end at the right moving upward several times as fast. In this the actual slight increases in the length of the wire (due to increasing the weights suspended) are multiplied by the number of times the distance from the end of the pointer to the fulcrum is greater than the distance from the fulcrum to the wire. In this way, if wires of different materials, but like diameters, are available, comparisons of the streching characteristics are possible. Iron wire, copper wire, and resistance wire should be relatively simple to obtain.

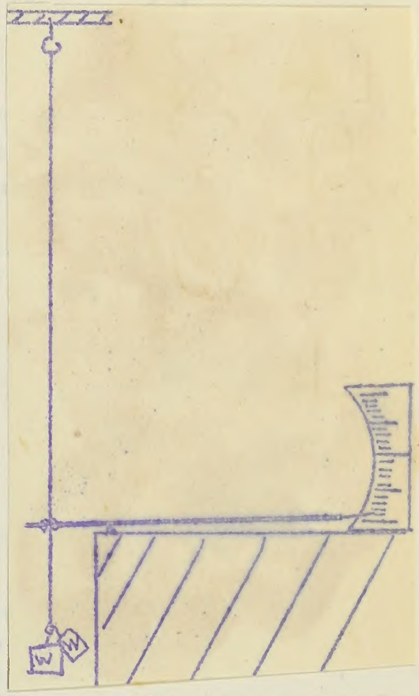


Figure 155. A sensitive stretch-measuring device.

2. Likewise, the coefficient of tensional expansion of each of the materials concerned may be determined.

B. <u>Heat and solids volumes</u>.

The brass ball and ring is the classic means of showing that heat often results in expansion. In view of the tremendous variety of methods to bring out this idea, it seems no longer necessary to require this piece of apparatus from the

supply houses. Several experiments dealing directly or indirectly with this particular problem are here described:

1. Two screw eyes of the same size are fixed to pieces of wood as in Figure 156. Heating of one prevents the slipping of it by the other. Heating of the other makes it possible to slip the first by the second.

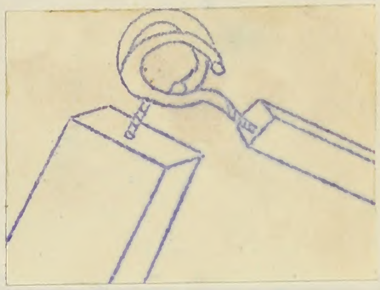


Figure 156. A substitute for the brass ball-and-ring.

2. Find a large threaded bolt and a washer which will just barely pass over it as shown in Figure 157. Heating of the bolt makes it too large for the washer, but the bolt when cold is easily surrounded by the hot washer. The washer is so firmly fixed as to be difficult to remove with a hammer if the bolt is heated again while the washer is on the bolt.

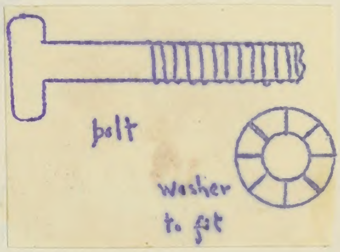


Figure 157. Bolt and washer expansion apparatus.

3. Mount a metal sheet in a horizontal position to a wooden frame as shown in Figure 158. Heating this will cause a pointer is provided for by having it attached to the end of the glass tubing, itself acting as the roller for the expansion bar. The heat comes from a flame running along underneath the expansion bar.

4. In Figure 159, a coefficient of linear expansion apparatus comes from a discarded Liebig condenser, only the

water jacket of which must be entire. Each of the steam passages (as the condenser is usually used) is fitted with a single-hole stopper which is pierced by the metal bar to be subjected to the steam temperature surroundings. One end of the bar rests firmly against an immovable object, and the other end operates an indicator. Live steam from a boiler circulates through the usual water jacket. To make another type of indicator drive a long thin nail through the barrel of a spool. Pivot the spool on a second nail through its core. A piece of paper or stiff wire fastened to the longer protrusion of the first nail can be used as the indicator while the shorter end rests against that which is being measured.

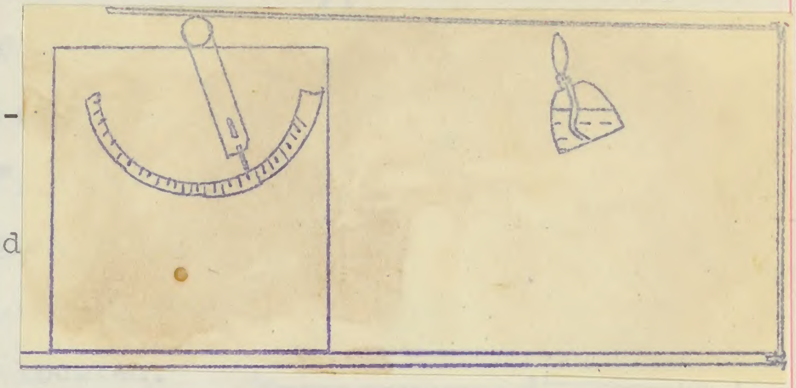


Figure 158. Flame causing the expansion of a solid.

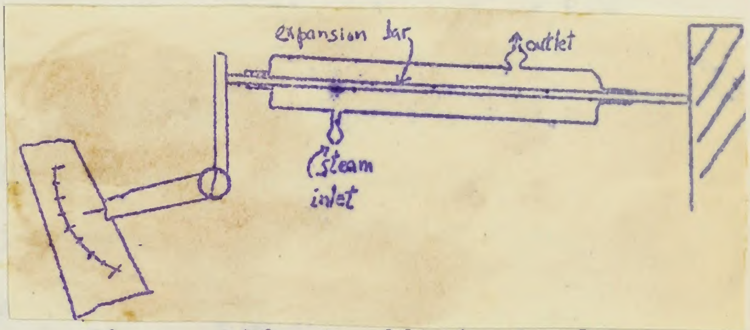


Figure 159. Coefficient of linear expansion.

5. A simple expansion device for ringing a bell is illustrated in Figure 160. Expansion and contraction, respectively, of the upright of the ring stand, causes a steel knitting needle to break and make contact with a dish of mercury hooked into the bell circuit.

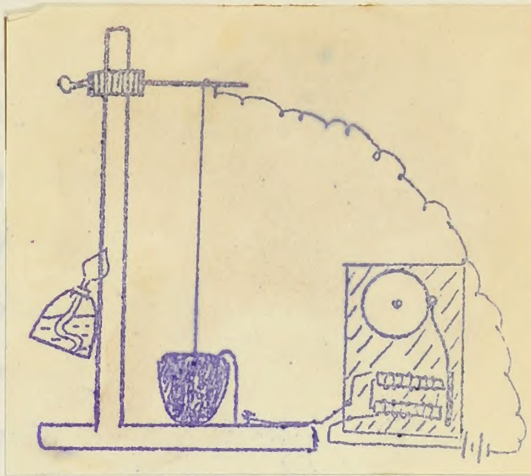


Figure 160. Expansion of the ring-stand bar breaking the circuit.

6. Another bell ringer applies the principle of a thermostat. This makes use of a compound bar of iron, "tin", and copper. This device of Figure 161 is operated by the heating of the air where the thermostat is located. In this compound bar, the copper strip on the inside of the bar, expanding faster than the tin, causes the bar to bend backward, and thereby to complete the circuit ringing the bell.

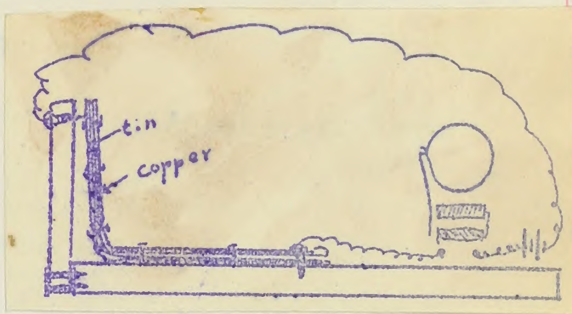


Figure 161. Thermostat ringing the bell.

7. Perhaps preliminary to the use here of the compound bar, it is wise to perform an experiment which, in greater detail, than in that device, illustrates the linear change of two metal s sheets of unlike composition. In the crude apparatus of Figure 162 can be seen such a device. It is not imposing or shiny, yet its use brings out the principle important to the thermostat.

In like manner, the apparatus of Figure 163 is easily improvised by a little workmanship. A strip of copper sheeting and a similar strip of flattened "tin" with three or four rivets provide all the needed materials.

8. The effect upon the linear measurements of a metal wire heated by an electric current is shown by the sonometer-like arrangement of an iron wire, held tight by a sizable weight suspended over a pulley wheel. The wire provides the material through which the current will travel. A paper folded in the middle and laid across the wire indicates the temperature change, while a strip of paper attached to the axle of the wheel around which the wire passes, indicates a measuring device for the expansion and contraction.

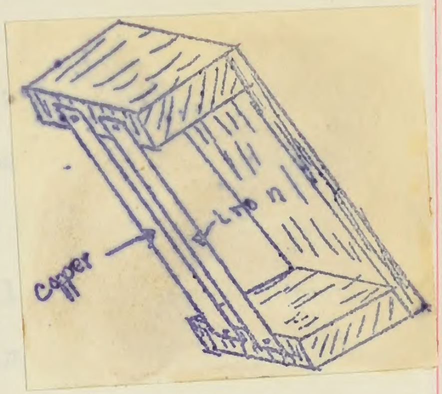


Figure 162. Effective to show unequal coefficient of linear expansion.

C. Heat and fluids.

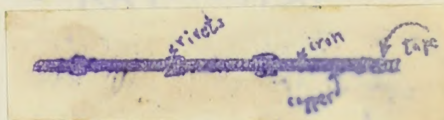


Figure 163. A simply-made compound bar.

1. Place outside on the doorstep on a cold night a glass container filled with ice-cold water. An ink bottle or a canning jar are good because their covers can be fastened tightly. Or, as in Figure 165, entirely surround the container with ice and

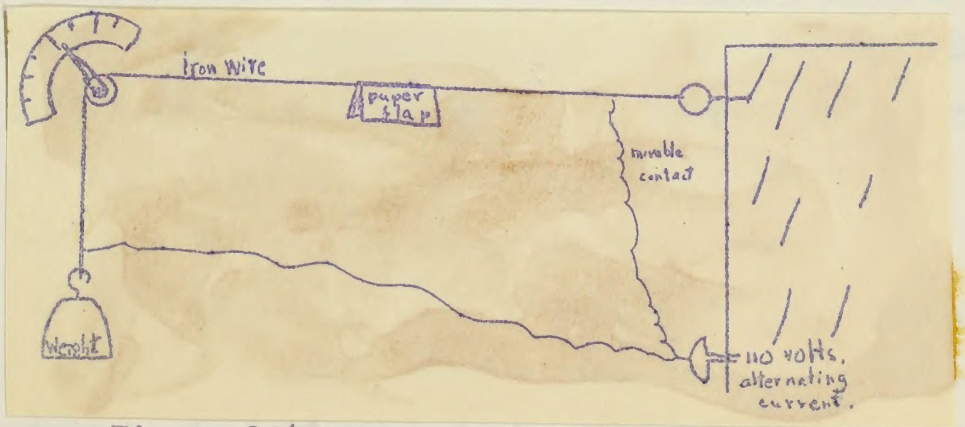


Figure 164. The electric heating effects on linear measurements.

salt in a wooden bucket.

2. A large jar is filled with water which is colored with a few drops of ink. Water containing little dissolved air by pre-boiling is better. The bottle is fitted with a one-hole stopper carrying a long glass tube as shown in Figure 166. These are forced into the larger container which causes excess liquid to rise in the tube. A marker is attached to the tube at the initial water level. Now slowly apply heat to the large container in such manner as to have no fracturing effects upon the glass.

A tub of water may be used as a container for the large glass jar as its temperature can be regulated more easily.

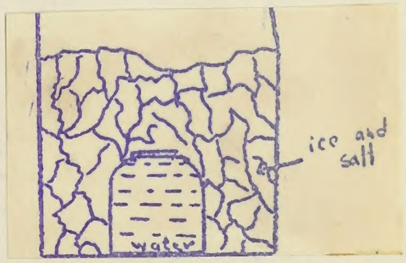


Figure 165. Showing the expansion force of freezing water.

3. The effect of temperature indirectly upon the density of the fluid may be brought out as shown in Figure 167. Two containers are balanced on opposite ends of a rigid bar; cold water in one, and warm water in the other. If like quantities, volumes are used in each case, it will result in a loss of balance by the stick. This suggests the idea involved in the change of density.

4. Any thin-walled glass container may be used to show the "air thermometer". Find a stopper to fit the container and into the stopper insert a glass tube with its long end, containing a drop of water to be used as an indicator,

extending upward. The heat of the hand indirectly causes changes in the level of the drop of water.

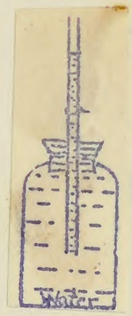


Figure 166. Expansion of water by heating.

If this set up has the addition of a hose attached to the protruding glass tube and leading into water, a greater range of visibility is effected. The bubbles seen and heard in the water indicate the effect of heat upon an enclosed gas.

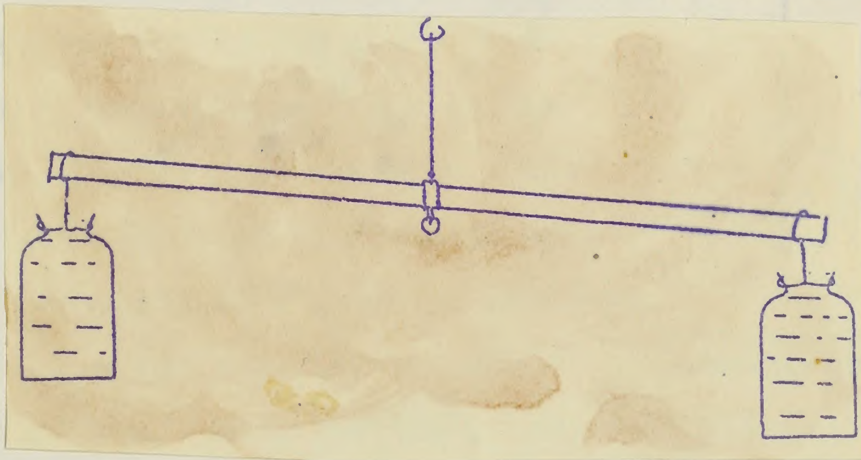


Figure 167. Hot water weighing less than cold.

5. Actual construction of an air thermometer is shown in Figure 168. In addition to the materials referred to above, a small thin board, marked with appropriate scale markings, two hasps and small nails are necessary. A small part of the board is cut out to make a place for the jar of water. If sensitivity to slight change is desired, a tube of small diameter is used.

6. The actual construction of a liquid thermometer is possible with a piece of special, thermometer glass tubing.

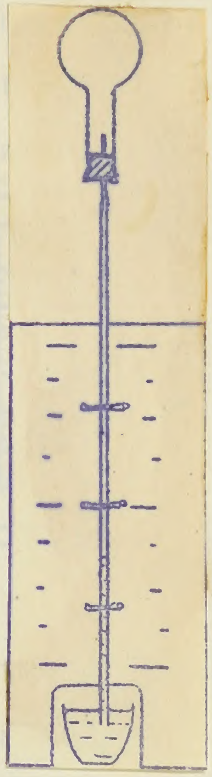


Figure 168. An air thermometer in use.

Figure 163 illustrates the various steps in the process. A 10-inch piece of thermometer tubing, a Bunsen flame, some kerosene and iodine, a glass funnel and a piece of rubber tubing are the materials necessary in order to build it. A piece of board, a ruler, a marking device, and two or three hasps complete the list of essentials. First, seal one end in the flame. Then heat about a quarter of an inch of the sealed end to white heat and blow a bubble about one-half inch in diameter with this end. Practice on a piece of ordinary tubing in which the diameter is one-eighth of an inch. Hold the end of the tube between thumb and forefinger, press the latter tightly against your lips as they surround the end of the tube, and puff out your cheeks. Blow only <u>into</u> the tube and only when the other end is white hot. Try an atomizer bulb if unsuccessful with breathing pressure. Next attach a funnel to the open end of the tube and pour in a little kerosene colored with iodine. Make room for the liquid by heating the air in the bulb. Remove the bulb from the flame to allow cooling. The air remaining inside contracts, and the air pressure on the outside forces some liquid down into the bulb. In order to fill all the bulb and stem with

liquid, boil the small amount of kerosene in the bulb which causes kerosene vapor to force out the air; when the bulb is again cooled, the condensing kerosene leaves a near-vacuum

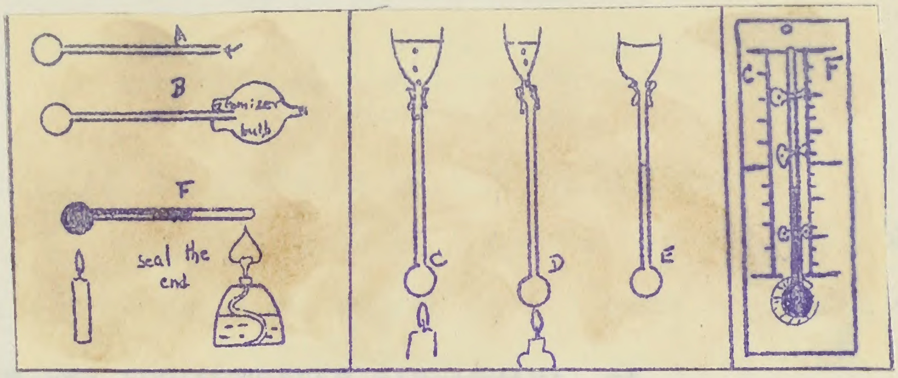


Figure 169. Steps requiring simple technique in making a thermometer.

in the thermometer. Air pressure forces more of the kerosene into the stem and bulb. Then after the liquid has cooled to room temperature, pour out the liquid remaining in the funnel and detach it. Since the liquid in the tube should stand at about the half-way mark to allow for both expansion and contraction, it may be necessary to pour out a drop or two of liquid.

Before sealing the open end, drive up the liquid by gentle heating with a candle flame until it is about an inch from the top. After sealing, let the thermometer cool. In this way, the space above the liquid is practically a vacuum. Too much air would interfere with the rise of the liquid in the stem. Both Fahrenheit and Centigrade scales may be made between the freezing and boiling points of water.

Another way is to compare the unmarked thermometer with

a standard thermometer at two different temperatures in order to be able to fix two definite accurate marks on the new thermometer.

The Physical State of Matter Depends upon and Affects the Conditions of of Its Surroundings

A. Effect of pressure on boiling point.

1. Figure 170 shows a simple set-up, both phases of which may be put into action at the same time provided there are two thermometers available. If but one instrument is to be used the temperature of the boiling water is determined after a minute or two of boiling, and then a delivery tube, added to the steam escape, takes the steam deep into a cylinder of water. In this way a slight increase in the pressure may be found to cause a slight increase in the temperature of the boiling fluid. As a check, after a minute or two of boiling under this pressure, the delivery tube is taken out of the water, allowing the pressure to fall back to its normal. If the temperature increase is insignificant lay the rubber delivery on the bench so that the steam spurts across it. Keeping one eye on the level of the thermometer liquid, gently apply pressure to the steam by "stepping" on the end of the hose by means of a

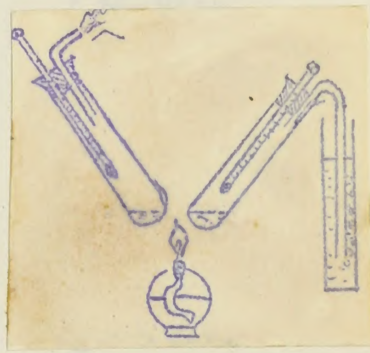


Figure 170. A different boiling temperature of the liquid observed in each case.

pencil or similar object. Use care not to apply sufficient force to cause the stopper to be blown out.

2. As a preliminary to the usual experiment concerned with an explanation of the "vacuum-steam" heating system, vacuum distillers, and mountain cooking, the device of Figure 171 may be useful. A small amount of water in a test tube is boiled for two minutes to allow the steam to force out the air. A balloon is stretched over the end of the tube and as soon as the steam has caused the balloon to fill out the test tube is removed from the influence of the flame. The balloon is found to be an effective measure of the speed of condensation of the steam.

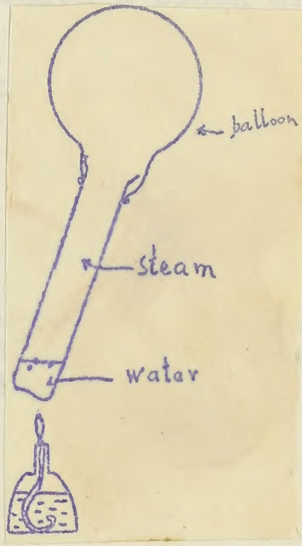


Figure 171. The balloon acting as a monometer.

The usual experiment is that which shows water boiling at a temperature of less than 100 degrees Centigrade, under a cold water tap, for example. In figure 172, the water is represented as boiling vigorously even though its container is surrounded by the cold tap water. It is necessary to force out as much air as possible (two or three minutes of boiling with the opening up) and to cap the opening tightly just before removing the boiler from the flame. A rubber stopper is preferred to a cork stopper and a test tube may be used as a container. It is not essential to use a thermometer as a

temperature indicator, because not only is the boiling effect easily seen, but also, the experimenter can, after several minutes have elaspsed, hold the boiler in the palm of his hand with less and less discomfort.

B. Affect of pressure on freezing point.

1. The regulation experiment in which a block of ice is severed by a weighted wire, and found after the splitting to have re-frozen when the abnormal pressure is relieved.

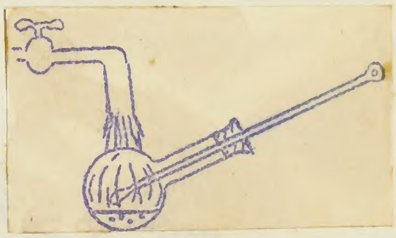


Figure 172. The water boiling at 60 degrees Centigrade.

2. A coin placed upon a block of ice is soon found imbedded in the ice.

C. Evaporation, a cooling process.

1. As in Figure 173, plug the opening at the bottom of an earthen pot and nearly fill the pot with water. Place a similar quantity of water in a non-porous vessel having approximately the same size of opening as the vessel of earthenware. The first container will be satisfactory if it is sufficiently porous to allow the water to seep through and keep its walls moist. The second container is satisfactory if of glass or glazed wáre. If there is much difference in the temperature of the room and that of the water, a metal container is unsatisfactory. A thermometer kept in each or changed from one to the other may be necessary. On days when there is little water vapor in the air, evaporation

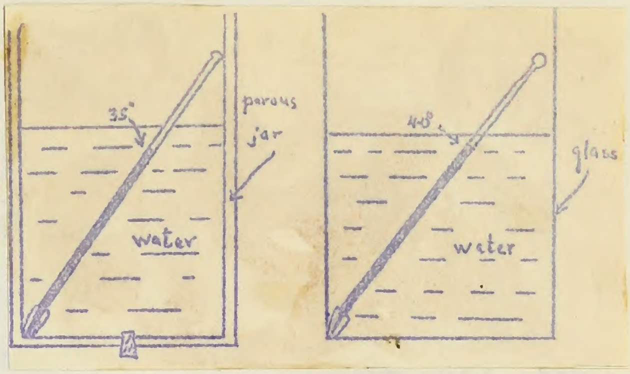


Figure 173. Cool by evaporation.

and the loss of heat resulting may be sufficient to be indicated by the actual feeling of the water.

2. Increase the speed of evaporation by using a shallow dish of ether and an air pump to increase the rate of circulation of air, as in Figure 174. In this way water may be frozen in three or four minutes.

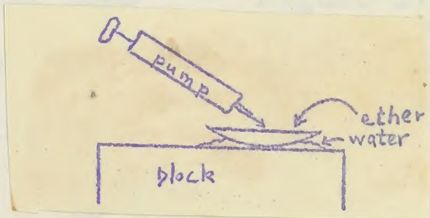


Figure 174. Evaporation to freezing.

3. Dip one finger into alcohol, another in gasoline, a third in water and blow upon them, or wave the hand in the air. A difference in temperature may be explained by the different rates of evaporation. A more accurate approach is indicated by using thermometers, the bulbs of which have been wrapped in cotton and dipped in different liquids. It is not necessary to have as many thermometers as liquids tested. One can be used satisfactorily if a chart is made in which to record results.

4. An iceless refrigerator is made as indicated in Figure 176. Surround a wooden or cardboard box with an absorbent type of cloth of sufficient area. Keep the cloth

covering in a continually wet condition.

As a means of explaining both the iceless refrigerator and the porous jug method for keeping liquids cool, use the arrangement of Figure 177. Any two like containers, for which one-hole stoppers may be found to fit, are satisfactory. The glass tube acts like an air thermometer and its use may cause the partial filling of the neck of the container.

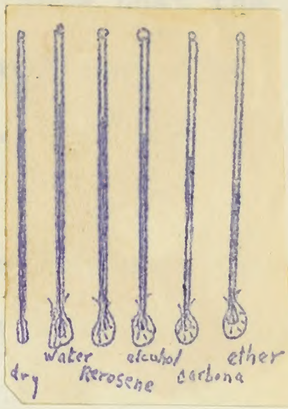


Figure 175. Rate of evaporation determining temperature.

5. A procedure requiring no special apparatus may develop ideas other than that evaporation is a cooling process. If one of two spots on a slate (blackboard) is heated to a considerable temperature by a direct flame and both swabbed over with a wet cloth one may readily see which of the spots loses its moisture the quicker. In like manner a third spot may be made with the first two, and some pupil set to the task of fanning it with a large sheet of stiff paper. In these two steps, the relation of the rate of evaporation to the amount of heat available, and to the rate

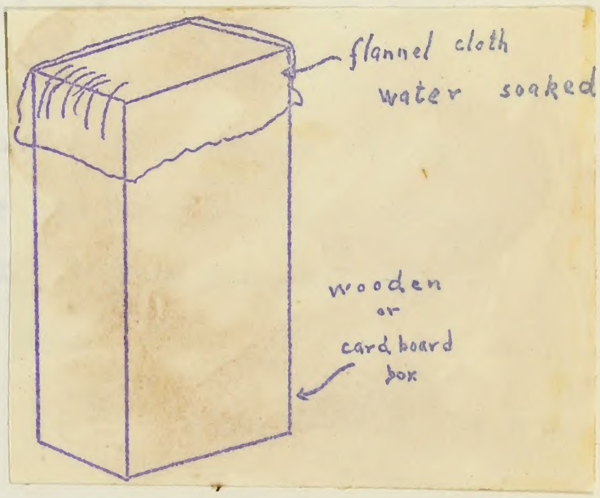


Figure 176. An iceless refrigerator.

of circulation of air may be determined. To show that the rate of evaporation depends upon the fluid used swab over one area with water and another with alcohol.

D. Condensation liberates heat.

1. When people say that a steam burn is "hotter" than a burn by boiling water, the above principle is involved. As in Figure 178, direct a stream of steam at a bulb of water in which is immersed the bulb of a thermometer. Rearrange this by taking the thermometer out of, and inserting the delivery tube into the water, and by placing all of it so that the test tube can be placed under or removed from water flowing out of the tap. The tap water, running over the exterior of the test tube makes it possible to change the distance which bubbles of steam will travel upwards from the end of the delivery tube before condensing.

2. There are many simple apparatus arrangements to develop the principle underlying the operation of a steam heating system. The bottles in their inverted positions of Figure 179 are equiped so that the tubes to each radiator should not protrude beyond the stoppers.

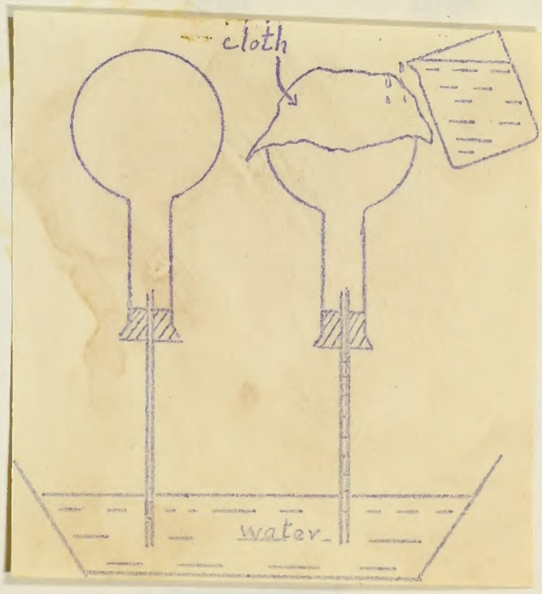


Figure 177. The iceless refrigerator explained.

This illustration does not show clearly that the pipe running from one "radiator" to the other is sloping.

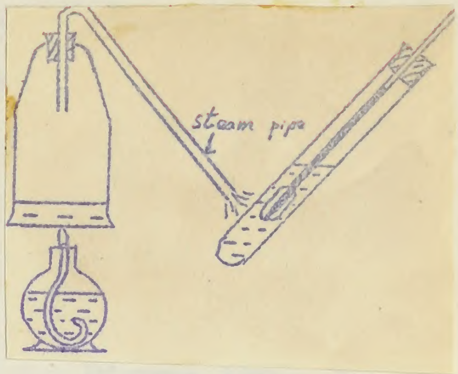


Figure 178. Heat of condensation.

E. <u>Condensation in a cooler surroundings</u>.

1. The dew on the cup or glass of ice water is one example.

2. A cold dry plate is inserted for a moment into a stream of steam from a kettle of boiling water.

3. In Figure 180, a one-hole stopper carrying a short glass tube is fitted to a transparent bottle. An air pump forces the air to be compressed inside the bottle. When too much pressure is exerted the top blows off and the rapidly expanding gas inside is so cooled as to lose its water vapor by condensation. This explains the fog. Some people would say that the energy necessary to hold water vapor in the air is changed to the energy of expanding air particles.

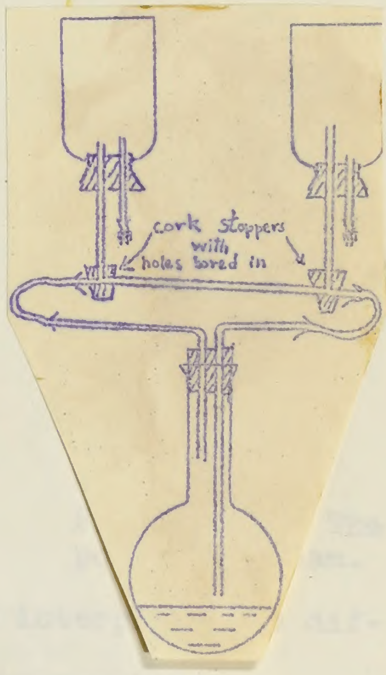


Figure 179. A steam of the single-pipe arrangement.

F. <u>Particles of gas in more rapid motion</u>.

1. The commonplace apparatus of Figure 181 indicates in its explosion results that increased force of bombardment resulting as a liquid changes to gas. If notice is taken of the bottom of the stopper, it will be found to carry evidence that the nature of the liquid has not changed. Water has condensed on it.

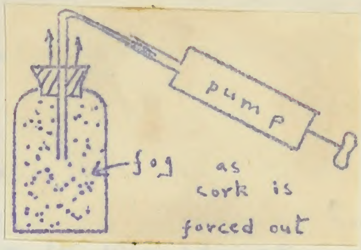


Figure 180. To make a fog.

G. Atmosphere changes causing changes in state.

1. A manilla rope may be a substitute for a barometer. It is tightly fixed between two hooks and should be 20 to 30 feet in length. A graph can be made to show the relationship of the barometer reading and the amount of sag existing.

2. A simple hygrometer results from comparison of the readings of two thermometers. The protective metal grill is removed from one and a cotton wad is tied to its bulb. This wad is kept moist by dropping water on it, or by having the wad long enough to dip into a shallow dish of water. Many general-science texts carry a table which interprets the difference between the readings of the two thermometers.

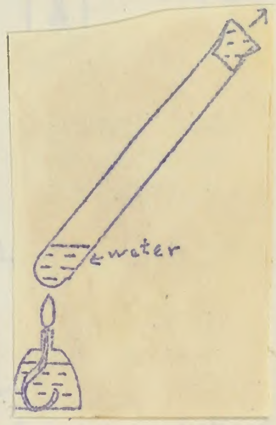


Figure 181. The power of steam.

3. When the amount of water vapor in the air can

noticeably affect the nature of certain chemicals another type of hygrometer may be worked out. Soak a strip of any type of paper in a weak solution of a cobalt salt, (chloride is satisfactory) and let the paper, evenly colored, dry out. Cobalt salts have a tendency to become blue when drying out and to turn back to pink when in a moistened condition. The different proportions of water vapor in the air are sufficient to obtain visible results. sympathetic inks, rag doll weather men and the like have their construction determined by this fact.

Figure 182. The amount of water vapor in the air affecting the length of a rope.

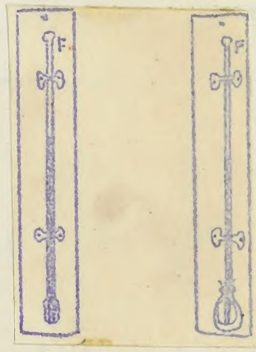


Figure 183. The simple hygrometer.

4. The cobalt salt method and the change in tension of a cord by action of atmospheric conditions make a combined piece for determining the weather. A pair of French dolls balanced with shot and hung from a gut string are mounted on a turn-table. The changing tension of the gut causes an axle, a thread spool turning about a nail, to move. The small amount of motion of the axle will be multiplied by the set of gears operating the turn-table. The dolls are

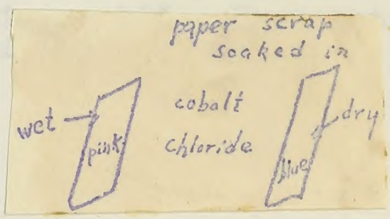


Figure 184. The paper hygrometer.

clothed in paper soaked in the cobalt salt. This is extremely sensitive having been found to shift during an hour's time.

5. The formula for the "cloudy" type hygrometer-barometer of Figure 185 is:

water...............	2 ounces
absolute alcohol....	2 oundes
ammonium chloride...	$\frac{1}{2}$ dram
potassium nitrate...	$\frac{1}{2}$ dram
camphor.............	2 drams

This solution is sealed in a test tube and mounted on a board covered with black drawing paper (as a background). White crystals are formed which settle to the bottom in fair weather and which otherwise separate throughout the liquid. If no crystals form, a few drops of water must be added until they do. If the precipitation is too heavy, a few drops of alcohol will dissolve some of it. If 95 degrees alcohol is available instead of the absolute, a little less water should be added.

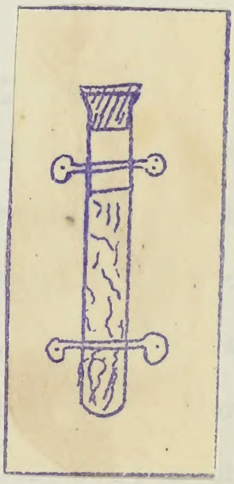


Figure 185. Hygrometer of the "cloudy" type.

CHAPTER V

ORGANIC MATTER, OF SENSITIVE DYNAMIC MATERIAL, REQUIRES CERTAIN PHYSICAL QUALITIES IN ITS ENVIRONMENT, EFFECTS CERTAIN CHANGES THEREIN, AND HAS FUNCTIONAL STRUCTURE.

Living Things Require Certain Physical Qualities and Materials in Their Environment.

A. Providing the food necessary for growth.

1. A large number of oat seeds started in a seed tester, (see discussion concerned with Figures 207 and 208) having germinated, is evenly divided and transplanted to six-inch flower pots containing sterilized sand. Material additions to five of the pots are made as follows: number one, a quarter-teaspoon of ammonium nitrate; number two, a third of a teaspoon of potassium chloride; number three, a half-teaspoon of rock phosphate, or of bone meal; number four, a layer of clay, a half-inch deep; and number five, a half-inch layer of garden soil. Each of these is watered to make the food in solution available to the roots.

To show more definitely the minerals required, five wide-mouth bottles are used as containers for young seedlings in distilled water. To each in turn a pinch of the following

materials, respectively, has been added: potassium nitrate, magnesium sulphate, calcium sulphate, and potassium phosphate.

To determine the effect of different mineral deficiencies upon the growth of a plant, raise seeds of a specific plant on "Pffeffer's Solution", the formula for which follows:

calcium nitrate....................4.0 grams
potassium nitrate..................1.0 grams
magnesium sulphate.................1.0 grams
potassium dihydrogen phosphate...1.0 grams
potassium chloride.....................trace
distilled water..............3 to 7 liters

The seeds are held in place over the solution with cheese cloth after the seeds have been germinated. To deprive seeds of:

1. Calcium, use sodium nitrate for the calcium nitrate.
2. Nitrogen, use calcium and potassium chlorides, not nitrates.
3. Potassium, use the three sodium salts instead of the potassium salts.
4. Phosphorus, use potassium chloride.
5. Magnesium, use sodium sulphate.
6. Sulphur, use magnesium chloride.

The seeds are held in place over the solution with cheese cloth after they have germinated. It would be interesting to photograph these results.

2. To see that food is provided for the germination process by the seed itself, remove the cotyledons from each of half of a group of bean seedlings, and plant them so that the plumes show through the ground. In this way the function of the cotyledon as a soil breaker for the plumule is not a factor in the experiment. Since to perform the cotyledon operation, the process of removing the seedlings from the soil

might harm the tender roots, it is better to develop the seedling in a seed tester.

B. Proving the amount of light necessary depends on the organism.

1. Place several living earthworms on top of some moist loose soil exposed to the strong sunlight. Exposure to either the light of a 100-watt electric lam, or to the light of a carbon arc is a satisfactory substitute for the sunlight.

Place a light source at one end of a lamp chimney. Absorb heat into the lamp by a water lens or other glass condenser. Observe the reactions of fruit flies placed in the chimney. (Fruit flies, are the small, black, fast-moving insects seen wherever decaying bananas, pears, and similar fruits are found.)

2. Bacterial response to light, and the needs of bacteria for light may be developed in the following way: Rub the end of a needle into a culture garden which is thriving with bacterial growths, and with the needle inoculate a sterile garden in several places. Cover the dish with black paper except for a small hole near the center. Then place this culture in the strong sunlight, and after several days exposure examine to see where growth has occurred.

3. Place a potted plant in the window noting the position of leaves and stems. After several days turn the container 180 degrees and observe for changes.

As in Figure 186 a hole is cut in one end of the side

opposite the sliding door of the wooden chalk box. In addition, two cardboard walls which are long enough to divide the box into sections as shown, are attached to the side walls. A seedling is transplanted to the layer of soil at the bottom of the box. This is set in a warm sunny window. After several days (keeping the box in a warm moist spot at night) note the direction of the growth of the stem.

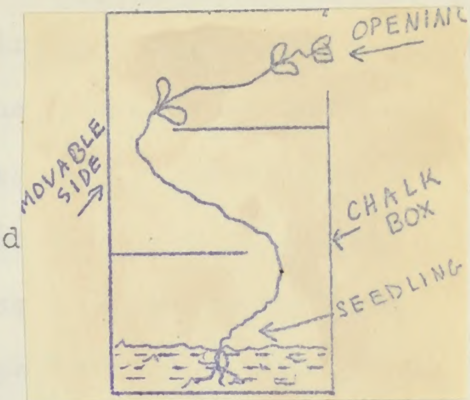


Figure 186. A seedling seeking light.

C. Certain chemicals in the environment determine the possibility of growth.

1. Culture gardens are inoculated with fertile injections and the surfaces of each are treated with a swab of various reputed disinfectants such as iodine, carbolic acid, chlorazine solution, mercuric chloride, sulpho-naphthol, dioxygen, Mercurachrome, and any others desired.

2. That yeasts need food in their environment is an idea which may be developed as follows: Stew a few raisins for a half-hour. Place some of this material in each of two pint jars and also a piece of a yeast cake in each. Tightly cover one and leave each in a warm place for about a week. No yeast is necessaary if one of the jars is left unexposed to the air, and the other sealed.

Label four drinking glasses from 1 to 5, respectively. Divide a yeast cake into quarters. For three or four minutes

D. Providing an air supply.

1. The idea of the air requirement for water animals is developed very simply by applying the oil-control measure for mosquitoes. Mosquito larvae or dragon-fly larvae may be collected at any season during which the surfaces of ponds are free from ice. Plunge a small glass bottle, mouth down, to the bottom of the shallow stagnant portion of a pond or a stream. If the jar is slightly tipped up from the floor of the body of water some of the air in the jar will be replaced by that water. Hold the water-filled jar up to the light to examine for "wigglers". They are nearly transparent, from a quarter to a half inch in length, narrow in the middle, and have somewhat bulbous tufted ends. If none are present in the jar try again. When one is collected, drain off the surplus water, and pour the wiggler into a storage vessel. In this way a dozen or more larvae may soon be collected. Back in the laboratory divide the larvae into two groups keeping both in a glass container partly filled with pond water. To the top of one of these add a few drops of kerosene. Watch to see what happens as the kerosene strikes the water. From time to time observe the difference in the actions of the two groups of larvae.

The principle of prevention is as simple as that of extermination. Any time from late spring to early fall open vessels partly filled with water are set on the ground near

boil one quarter of the yeast cake in a cup of water half filled. Pour this into number 1 after it has cooled. Dissolve each of the other parts in a little water and pour the portions into the other three glasses. Put two teaspoons of syrup or some other sugar solution into numbers 1, 2, and 4; none in number 3. Fill numbers 1, 2, and 3 with warm water. Add ice water to number 4. Partly fill four shallow dishes with water. Put warm water into the first three and ice water into the fourth. Place cards over each of the tumblers and invert them into the proper dishes, respectively, numbers 1, 2, and 3 in warm and number 4 in ice water.

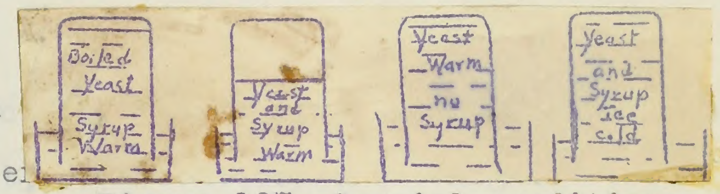


Figure 187. Special conditions for growth.

The experimental possiblities involving bacteria and yeasts are almost numberless. Such procedures test the effects of cold, warmed, and boiled environments; types of food for the culture; purity of the air; the amounts of moisture; the different exposed surfaces; and the different lenghts of time for heating. Different agar-culture preparations are found in the latter part of this chapter. The pasteurization of milk is accomplished in the standard manner, that is, by heating the sample for 20 minutes at 145 degrees Fahrenheit, 62 degrees Centigrade, and plugging the container with sterile cotton. Controls are usually introduced as part of each procedure.

some shrubs around which mosquitoes may often be found. To one of the vessels a teaspoon of kerosene is added. Since this material is quite volatile it is necessary to add to it. Again, by covering a third jar with a piece of fine woven material the result is the same as that which the layer of kerosene produces.

2. To determine that germinating seeds need air as well as moisture and heat, soak some seeds overnight. Then place an equal number in each of two bottles containing moist blotting paper. Cork one bottle tightly and leave the other open. In addition, seal the one with melted paraffin. Both bottles are set in a warm place and are examined at the end of a few days.

3. The manner in which fungus diseases enter an organism and the conditions of growth required in the organism are shown by treatment of several apples with sterile and fertile inoculations. The outside of a number of apples is first sterilized by immersion in 95 per cent alcohol and after a few minutes are washed with sterile water. A small cork-borer or apple corer is sterilized and pushed into the apple a half-centimeter. The borer is withdrawn, together with the piece of apple it has cut out, and a fragment of the thread of the brown apple-rot fungus is placed in the pit. The portion of apple tissue is then pushed back into place by a sterile glass tube passing through the center of the block.

To prevent entrance of other organisms the cut is sealed by pouring a little melted paraffin over the wound.

Repeat the same process with the control apple, except that a sterile needle is rubbed into the pit. The apples thus treated are placed in a sterilized, covered, battery jar where it is quite warm. In a few days watch for the appearance of the brown rot. Incidentally, the inoculated apples offer good specimens for the study of the stages in the life history of this fungus.

4. Certain microscopic forms are found to react like seeds in having an inactive stage of variable length, the spore stage. A hay infusion is made by letting dry grasses or leaves soak in a jar of tap water in a warm place from 15 to 20 days. This procedure usually results in a fine source of microscopic life which under the favorable conditions recover from the inactive spores.

5. Balanced aquariums show the living conditions for many types of plant and animal life. A battery jar may be used or a gallon glass container may be converted into an aquarium jar by cutting off the round top. Clean sand and pebbles at the bottom serve as a sufficiently firm bottom for the roots of many types of small aquatic plants. The plants useful are those which may be found growing with most of their foliage under water. In order not to hurt the tender roots in transplanting, a small pebble tied to the lower end will hold

the plant against the bottom until rooting takes place. Suggestions as to the animal occupants are nearly endless. A few follow: Minnows, snails, tadpoles, flat worms, "bloodsuckers", diverse larvae, "lucky-bugs", and other water beetles and skaters.

It is interesting in watching development to collect by the dipping and the inverted-bottle method, respectively, harmless appearing objects from the surface and the floor of the body of water. Placed in a jar in the house many of these objects may prove to be immature forms of water animals in general, which in the warmth of the house, will come out of their inactive stages. These form a collection which grow through the successive stages of their metamorphosis. It will be found necessary to separate some voracious forms and, also, to place nets over certain of the containers to prevent the escape of the adults. For instance, the dobson (dragon fly) nymphs and the minnows eat the mosquito larvae. A separate container is necessary for the larvae. Later it has to be screened.

Activities of Organisms Result
in Changes in Their Surroundings.

A. Activities of the usual types produce carbon dioxide and water vapor and use oxygen.

1. That the ordinary bodily activities of man effects these changes is convincingly shown by the use of the apparatus of Figure 188. The purpose, here, is to make actual

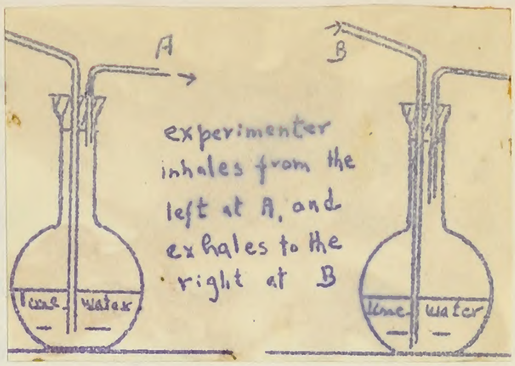


Figure 188. To compare inhaled with exhaled air.

comparisons of the amount of carbon dioxide exhaled and inhaled.

Increased water vapor can usually be shown by exhaling on a cold surface--glass, metal, or the like.

2. Evidence of increased oxidation as a result of exercise is obtained by the use of the arrangement at the right of Figure 188. By using the same chemical indicator, lime water, as above, the amount of the gaseous waste formed in a given length of time is determined by forcing all the air exhaled during that time through the tube "B". Two trials are run. First, the experimenter breathing normally sends all exhaled air through "B". The time required to cause the first trace of "milkiness" in the test solution is noted. Then the experimenter exercises vigorously and afterward blows all exhaled air through the solution in the same way and for the same period of time. A timing device in the form of the "seconds pendulum" makes a good substitute for a stop watch.

3. That aquatic animals add carbon dioxide to their environment is an idea easily described in experimental form yet one which requires patience to develop. One method is as follows: For a few moments leave a small living fish in a vessel of lime water. Does the appearance of the lime water change?

A second test apparently needs greater care and time. Place a small fish in a battery jar the bottom of which contains no more than enough fresh water to just cover the fish. After a half hour, suck into a glass tube a quantity of this water next to the fish. Take an amount equal to that of the capacity of a medicine dropper. This is placed in a quarter-vial of lime water with which it is mixed. This process is tried several times, if necessary, and using different specimens of fishes.

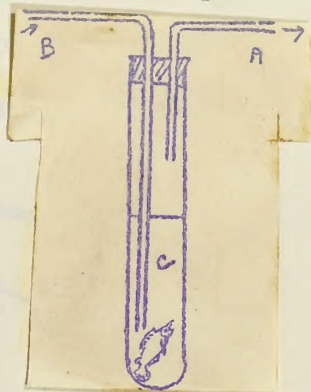


Figure 189. Changes due to oxidation.

Third, to about five cubic centimeters of water in a boiling tube add three or four drops of an indicator, (0.04 per cent cresol red). To "A" in Figure 189 attach an aspirator and draw in at "B" until a color equilibrium is established to indicate a certain concentration of hydrogen ions in "C". Compare the color of "C" with that of the liquids in a set of similar tubes containing standard solutions. Insert the fish or other small aquatic animal, note the time, and replace the stopper. As the organism excretes carbon dioxide, the strength of the solution changes which is indicated by the color of the solution, and when a sufficiently marked contrast has been obtained (five minutes or more) actual side-by-side comparisons with the standards are made and the time noted.

4. That germinating seeds give off carbon dioxide, and water, is developed as an idea by the following procedure:

Two large bottles are covered on the bottom to a depth of two layers with moistened blotting paper, or other absorbent material. In each a small vial or evaporating dish nearly filled with lime water is placed. One of the bottles is then filled at the bottom with seeds which have begun to germinate (soak over night) and both are then carefully sealed or stoppered. These two, one a control, are left for 24 hours.

Again, start 20 or 30 seeds germinating in moist sawdust or on moist brown paper. When the sprouts appear put the seeds in a small bottle the bottom of which is covered with sawdust, as shown in Figure 190. Plug the bottle with a two-hole stopper equipped as shown. Attach an atomizer "A", and connect the shorter protruding tube with a vessel of lime water. Remove the stopper equipment to let the seeds germinate for two or three days. Insert the stopper tightly and let the apparatus set for a half hour. Then force the air into and out of the flask by working the atomizer bulb. Watch for indicative results.

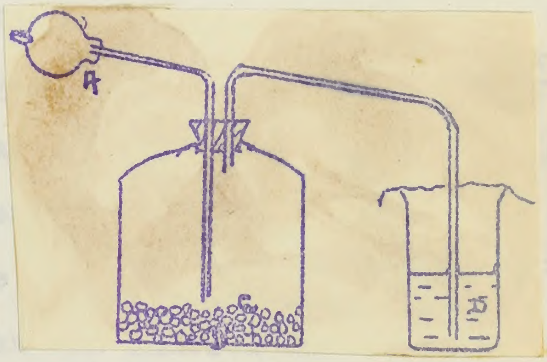


Figure 190. Changes due to germination.

5. That molds operate in the same way may be shown by substituting two pieces of slightly moistened bread which has started to mold, under a glass cover on a flat dish. At one side of the bread a watch glass holds lime water. Obser-

vations a day later of the condition of the transparency of the cover and of the color of the lime water are taken when the cover is removed. The changes indicate the effect which mold has upon its surroundings.

B. Life activities extract oxygen from the surroundings.

1. To develop the idea that germinating seeds use oxygen proceed as follows: Partly cover some germinating seeds in two bottles with water. Stopper only one as a means for later comparison. After they have set for a day or two insert a glowing splinter into each bottle in turn as a test of the condition of the air contained.

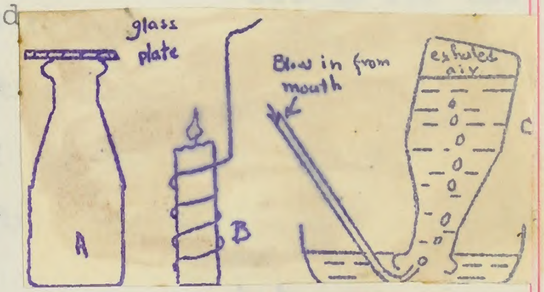


Figure 191. The oxygen in inhaled and exhaled air.

2. That people use oxygen from their surroundings is satisfactorily developed from the experiment which follows: The length of time which a given candle burns in fresh air is compared with the interval it will burn in the same volume of exhaled air. As shown above a candle is held firmly in a coil of flexible fine wire. The bottle, at "A" is supplied with fresh air in two steps: first, fill it with tap water; and second, empty the water. Now, take the time as nearly as possible during which this air will keep the candle burning. Time begins when the candle enters the mouth of the bottle. A glass plate is placed across the top and held firmly until the candle "goes out". At that

moment the elapsed time is measured. Then the same bottle is filled with exhaled air by the downward displacement of water as shown. The timing process for the burning is again repeated.

C. Green plants give oxygen to their surroundings.

1. An improvised bell jar is inverted over a small, potted, well-leafed plant beside which is a burning candle. The candle is found to become dim. It snuffs out in a few moments because of the lack of air. If a small burning candle is injected now under the cap, it is immediately snuffed out. The bell jar is now lifted to capture a new air supply, the larger candle is again lighted, and the bell jar replaced. This time after setting for a day in the sunshine, the air is again tested as before for oxygen content.

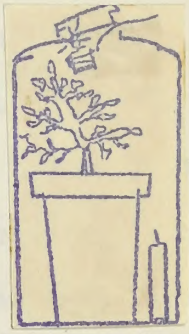


Figure 192. Set-up for the testing of photosynthesis.

2. Place a green plant, such as Elodea (some pond-scum, water cress, and marsh marigold or Parrot's Feather, commonly sold by florists for aquaria will do) into a battery jar, and cover the plant foliage with a glass funnel as shown in Figure 193. Invert a test tube of water over the small end of the funnel. Place the whole apparatus in a sunny window. After several hours, a gas will have collected in the test tube. Test it for oxygen with a glowing taper.

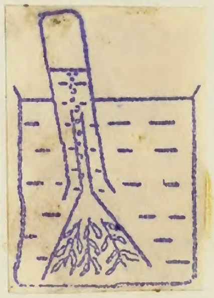


Figure 193. The bubbles coming from photosynthesis.

D. <u>Fermentation adds carbon dioxide and alcohol to the surroundings of yeasts</u>.

1. Figure 194, at the right, shows a flask, which contains a tumbler of water, enriched with some type of sugar solution such as Karo, molasses, honey, maple syrup. In it is dissolved a quarter yeast cake. This is set in a warm place for two days. To test the gas evolved, collect it by the water·displacement method and into one of the small jars as shown of the displaced gas, thrust a lighted splinter; in the other shake a little lime water. Next, examine the liquid in the fermentation flask. Smell of it. Heat a half pint of it in a simple still and catch a few drops of the distilled substance. Pour these drops on a plate. Alcohol is indicated if the material takes fire.

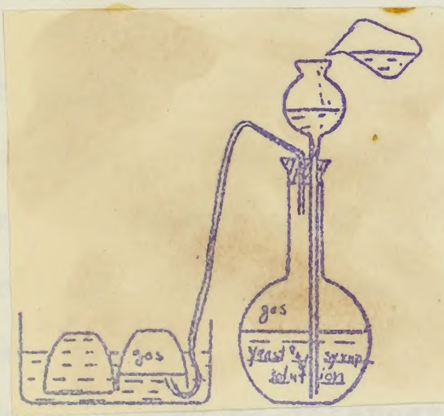


Figure 194. To collect gas for a test.

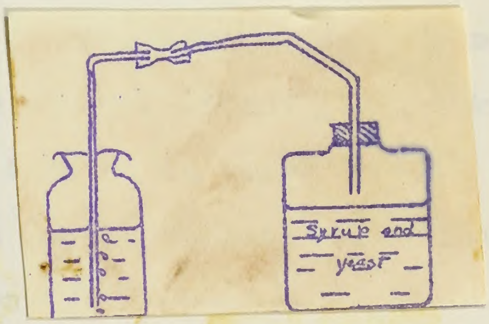


Figure 195. Fermentation.

2. A large container is filled with a contents of syrup and yeast in dilute solution. It is then outfitted with a gla s tube in a one-hole stopper. The apparatus is set aside for three days in a warm place. When the materials

which it adds to its surroundings are ready insert the delivery tube into some fresh lime water and watch for any effect of the bubbling gas upon the appearance of the lime water to indicate carbon dioxide. Uncork the bottle, and attempt to smell the odor of alcohol. The alcohol test is more effective if treated as in the paragraph above--by distillation.

3. The simplest arrangement is made by placing some molasses and a quarter yeast cake in a little warm water in one of the tumblers. Fill the tumblers, invert into a shallow pan and leave this overnight in a warm place. Test the gas in the first tumbler with a match, and in the second, with lime water. Smell the liquid in the pan for alcohol.

E. Bodily secretions convert foods to different forms.

In the usual experiments involved under this idea only one mention will be made of any of the many tests so commonly described in biology and in some general science textbooks. The reason for this omission is that since these methods are so well-known useless repetition may be avoided. Mention is made here of the single experiment discovered in this subject which seemed of interest to the author because of its seeming superiority.

1. Experimentally, starch digestion is usually indicated by testing for the presence of sugar after different samples of foods have been treated with saliva. The iodine-starch test must be understood and also the Fehling's solution test

for sugar. One objection, however, to commercial corn starch is that it, adulterated and refined, furnishes poor material for the iodine test. Hence, to prepare satisfactory starch of high grade: wash, scrape, and mash a large white potato. Place it in a piece of cheesecloth or thin handkerchief. Bring the corners together forming a bag. Half fill a large bowl with clear cold water. Dip the bag in the water and hold it there. Knead the bag quickly with the fingers for three or four minutes. Remove the bag. Let the bowl stand for fifteen minutes. Pour off the water carefully saving the starch at the bottom. Wash once more, then drain again, and finally scrape the starch into a sheet of paper to dry.

When textbooks of science say, "iodine solution," the thought of the antiseptic may come to mind. The proper iodine solution for the starch test should be made as follows: Put a few crystals of iodine into an ordinary drinking glass (the number of crystals you can easily pile on a ten-cent piece). Add a teaspoon of potassium iodide crystals. Nearly fill the glass with cold water and stir to dissolve.

Using the potato-starch extract and the prepared iodine solution insures satisfactory results.

1. The digestion of starch can be checked in various stages at definite time intervals by use of the apparatus and procedure indicated in Figure 196. A pinch of the prepared potato starch is put in a tumbler at "A" which is then half-

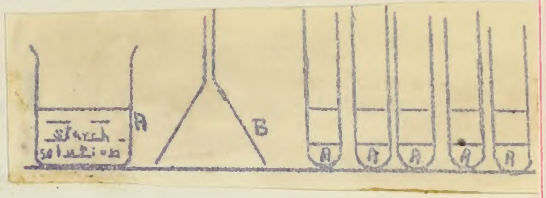


Figure 196. Starch to sugar progressively.

filled with water. Heat to boiling for a few minutes. Into each of five test tubes in the rack pour an inch of the starch solution. Let them cool until lukewarm. Put two or three drops of the prepared iodine solution into the first to show the starch test. Collect saliva by spitting through the funnel "B" into a beaker. Pour a generous portion of diluted saliva into each of the other four tubes, and at two-minute intervals, test each in turn for starch with two or three drops of the iodine. Compare the colors. Likewise, beginning with number five, test for sugar with Fehling's solution.

2. A simple reminder exercise is to answer the question: How does dry bread, cracker, or potato taste after a minute or two of chewing?

Structure of Organisms Is
Adapted to Function.

A. The efficiency of the parts of the eyes, and of their use together provides the degree of success in function.

1. The idea of the actual lens of the eye of an upper-class animal can be developed by procuring the eye of a cow, a pig, a horse, or other large mammal, and with sharp scissors, cutting away flesh to make possible examination of the lens. As a part of the observation look through the lens while holding it up to the light, or with it try to read some chalked words on the blackboard. A razor blade may be used

more effectively for the dissection. After the lens tests, as above, hold it by the rim and note its ability to bring light together to form images as is the case with a glass lens.

2. To bring out how the iris of the eye operates observe the iris changing the size of the pupil under varying light intensities. After several minutes in first, a dark room, and second, a bright place, examine the size of the iris and pupil in a mirror. In the two cases the pupil should show black in a large, and in a smaller area, respectively.

To show how the iris actually operates, examine the mechanical diaphragm on the underside of the platform of the compound microscope. Do the same with the adjustable shutter on a camera.

3. That a person with but one useful eye works under difficulties becomes understandable as a home-made model of, or an antiquated, stereoscope is put to use again. A person's simple analysis from almost any points of close observation may reveal that part of any one object is visible, or hidden, to one eye, yet invisible or in sight of the other eye. Such a situation is represented in Figure 197 in which only part of a key is visible to the left eye, yet from the same place the whole of the key may be in view of the right eye.

Figure 197.
As seen from the left eye.

The actual situation does not present itself for the same reason that one eye fails to as fully interpret images formed on the retina, that is, as here, there are but two dimensions to represent the three dimensions of the objects. Figure 197 merely represents what should be done. This is: Place a book on a table in a slanting position in front of you and very close to it place some convenient object such as a key so that the right hand corner of the book will shield from the left eye some of the space between the bound edge of the book and the key that is represented. Since two different images of each object are formed as two eyes are used, the correlation of the slight differences of each gives the overlapping and shaded effects characteristic of any object's three dimensions.

B. Accuracy of perception limited.

1. That we can often misinterpret not only what we feel and hear but also what we see, is easily brought out. Careful observation of each of numerous crossing lines in Figure 198 to question their straightness, continuity and size, and to question the length or size of different objects, and the nature of a figure will illustrate the ease with which error of observation creeps in. For example: Are the two lines at "a" the same length? Are the two fragments of "c" on the opposite sides of the three curved figures parts of the same line? Are the two broad lines of "B" parallel?

Turn the paper slowly while watching what appears to be a set of stairs. Does it continue to seem a staircase? (This part of the illustration, not excellently portraying the problem, is satisfactory nevertheless). Draw, in a landscape picture, equal <u>length</u> figures of people each at a different distance from the lower border of the picture. Which figures appear the tallest? Each of the above examples and many similar tests may be drawn on large sheets of drawing paper and kept as permanent observation tests.

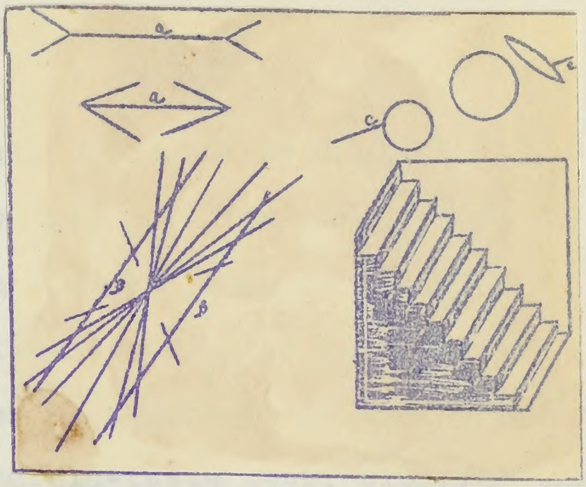


Figure 198. Tests visual perception.

2. To show that our touch feelings likewise are not dependable, do the blindfold sensitivity test which uses two sharp points like those of a small pair of scissors. The points may be separated at variable distances by means of a plug of wood or wad of paper held between the scissor handles by an elastic band. Any number of two-point devices may be improvised with pins and boards, sharpened pencil points, or pen points to provide "sticking" devices. Equally numerous are the devices which can be improvised to hold the points at varied distances. Clip them to a piece of paper, tack or staple them to the edge of a piece of soft wood. Bore holes

separated by different distances as the retainers in a piece of soft wood. Hold them on marked intervals of a ruler or meter stick.

Blindfold the subject. Touch different parts of his body with the two points and have him tell how many points he feels. In some places, the skin will be found to be quite sensitive. Accuracy of perception is indicated only as the subject scores higher than 50 per cent correct in his testimony.

3. In addition a blindfold-taste test, plugging the nostrils, will prove the ineffectiveness of the tongue's taste centers as a means of correctly identifying different liquid foods. The foods should be reduced to a fluid in order that the grinding-chewing process will lead to no clue as to the nature of the substance being tasted.

4. That our sensitivity to the temperature of the air is inaccurate, that we cannot judge degree of comfort by a thermometer reading, but that it depends more often upon the relative humidity of the air, the amount and kind of air in circulation, the degree of dryness of our bodies or of the clothes in contact with our bodies may be brought out by a large number of experiments. For examples, refer to the discussion in Chapter IV connected with Figures 173 to 176, inclusive, to see the numerous ways of illustrating that evaporation has a cooling effect upon the surroundings of the process. This cooling effect is due to the amount of heat taken

up as the gas changes to the liquid state.

C. Breathing apparatus functional.

1. To show the importance of the diaphragm to breathing perform, as is so often done, the experiment shown in Figure 199. Rubber dam and balloons, a cut-off gallon jar, and a Y-tube are the important parts. The bell jar is improvised by cutting the bottom away from a large acid bottle, and smoothing the cut with a corundum hone, or fine file and sand paper. Burn the alcohol soaked string which has been tightly tied at the desired height of fracture. Repeat several times until the temperature there is sufficiently high to insure the cracking off of the bottom when placed under the tap. Many times the Y-tube is inaccessible. It is a difficult problem to make a glass Y where a hot gas flame is not obtainable. To eliminate this objection, less significant pieces of apparatus, which merely demonstrate air pressure in action are used but which lack structure, as graphic as in Figure 199, to mimic the actual lung construction. Two of these air pressure substitutes for the apparatus of Figure 199 are shown in Figures 200 and 201. In the first of these, a tube one inch in diameter is fitted at one end with a one-hole rubber stopper, a glass tube, and a firmly-attached balloon. A plunger in the form of a circular wooden plug tightly wound with string, has a

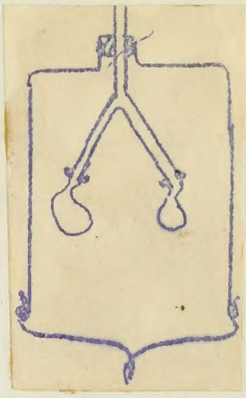


Figure 199. The lungs in action.

long nail or spike for a handle driven through its center. In the second, a hole is made with a rat-tail file in the bottom of a large flask or a quart jar, (see page 115) and a glass tube is cemented in with sealing wax. The attached tube is connected with a rubber and glass delivery tube to a funnel.

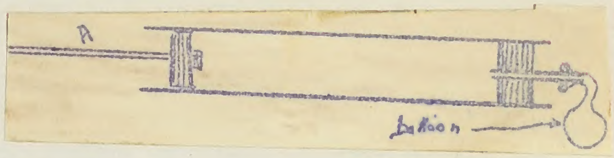


Figure 200. The plunger A is like the diaphragm.

Water is poured in the funnel until the bottle or flask is about half full. Then a one-hole stopper, glass tube and balloon, as in Figure 20 degrees are fitted to the top of the flask. The lowering or raising of the water level in the large glass container has its apparent effect upon the degree of inflation of the balloon.

2. That we have a much greater capacity for air than might at first be supposed, and that we usually use but a fraction of the breathing space provided by the lung's structure can be ascertained by measuring the capacity to breathe, using the apparatus of Figure 202.. Glue a strip of paper down the side, from top to bottom, of a gallon jar. Make a scale by marking the paper with heavy black lines as follows: Fill a common drinking glass and pour it into the bottle.

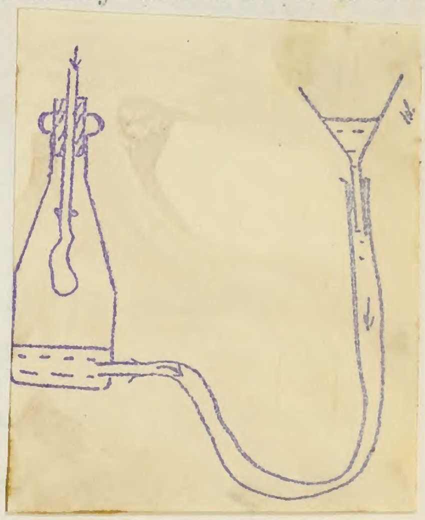


Figure 201. Air pressure and lungs.

Mark the water level on the paper scale. Add a second glass of

water and again mark the scale. Proceed in this way until the bottle is full. Cover the scale with a coating of shellac and let it dry. Each division of the scale represents approximately 15 cubic inches. The rest of the procedure is indicated in the diagram. The person being tested inhales as deeply as possible and then exhales in like fashion into the bottle. This can then be compared with a normal inhalation and expiration. The mouth tube should be either changed or sterilized after each usage.

D. Human voice box mechanics.

1. Stretch two pieces of sheet rubber tightly across the bowl end of a thistle tube so that each piece covers about half of the bowl opening. Fasten these in position with a rubber band. Blow into the open end of the thistle. What result explains a phase of the action of the vocal cords?

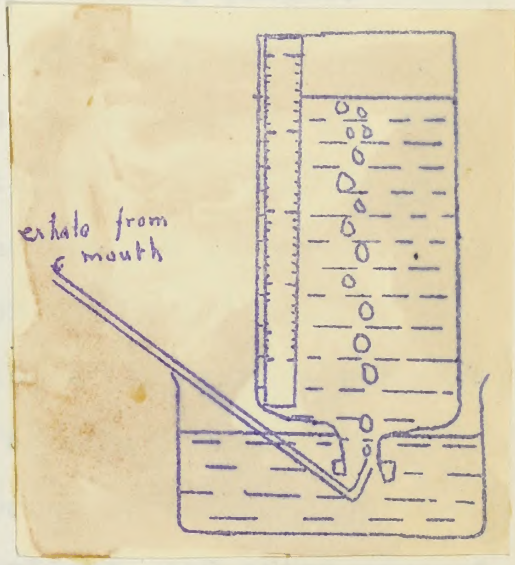


Figure 202. To measure your lung capacity.

E. Skeleton for adjustable support of the body.

1. Soak one chicken leg bone in dilute hydrochloric acid for several days. Notice the slow action, and carefully examine the resilience of the remaining material. Examination of this material develops the idea that the bony parts of a skeleton are by structure and composition adapted to the taking

up of shocks without undue danger of fracture.

2. Break into small pieces another leg bone by smashing it several times with a heavy hammer. Do this with the bones in a cloth container to prevent the scattering of the bits. Subject these particles to intense heat until they become gray and very brittle. This will bring out the idea that bones because of certain mineral content have sturdiness which provides the means of supporting the body weight.

F. <u>Leaves</u>, <u>roots</u>, <u>and</u> <u>stems</u> <u>as</u> <u>functional</u> <u>structures</u>.

As a basis for these experiments which concern the activities of green plants in making starch, the source of the raw materials for the process, and the changes incurred in the atmosphere by the return to the air of the by-products of the process, that is, the unused materials, a very common procedure is used. It shows green leaves as a manufacturing place of starch. Cover over, with a light, opaque material, a portion of a leaf not to be exposed to the sunlight, and after several hours remove the leaf and from it the cover material. Extract the green chlorophyll and then test for starch, first, in the exposed part, and second, in the portion of the leaf that was covered. The leaf may be partly covered on both sides in several ways. Use tinfoil, or light cardboard fastened firmly by paper clips. The chlorophyll is removed by immersion for several hours in strong alcohol. Some texts recommend the use of a day for each process, that is, a day for the exposure

treatment, and a day for the chlorophyll removal. Others recommend the use of faster methods, as for example, 15 minutes in boiling alcohol to remove the chlorophyll. After the preliminary steps, the iodine-starch test is performed.

That green plants give off oxygen and water vapor into the atmosphere as they manufacture starch has been discussed elsewhere in this chapter.

1. Different procedures are involved in bringing out the fact that plant leaves are constructed to provide for the passage of materials into and out from their interiors. The first of these requires a little in the way of home-made apparatus--a thin lengthwise section of a leaf can be prepared with a razor blade used as a microtome. Considerable practice is necessary. Some success is possible even to getting a section fine enough to show up, not only the stomates, but also the guard cells. Paraffin wax is melted on top of a geranium leaf (house plants as a general rule have a more adequate provision for transpiration than the garden plants or trees--swamp plants have large transpiration structures) till a layer less than a quarter-inch deep has been deposited. The leaf is then sealed under this block of paraffin the surface of which has been purposely melted. This block, solidified, is gradually peeled off with the razor blade; the wax holds the leaf firm, and soon a very thin section of the leaf's surface can be tried on the microscope table.

A much more effective procedure for many observers is to coat nearly equal-size leaves of a plant with wax, half of the leaves being coated on the under side, the other half coated on the top side (just two leaves are satisfactory provided a fairly sensitive balance is available). These leaves are then balanced against each other on a laboratory scale, or by tying all of the stems of each of the groups of leaves together, and counterbalancing them at the end of a meter stick suspended horizontally in the air. If each of the groups of leaves remains in the position of equilibrium for fifteen minutes sufficient time will have been provided to make possible an observation as to which of the group is losing weight the faster. This is an easily accepted approach to text discussions pertaining to structural adaptations in leaves for transpiration.

2. That the stem plays an important part as a pipe between the places of supply and use of the water necessary to the starch-making process, may be in a degree understood from finding the vascular bundles so common to many plants, or by seeing their ends in the cut-off stem of a cane plant. Their use may be shown by placing the stem of a plant having white tissue in eosin, or other deep coloring solution. Bleached celery is commonly used. Such stems should be cut under water to prevent air bubbles from entering to interfere with the action. A cane plant, such as a corn stalk, will so carry the fluid up its stem as to be quickly observable.

3. To show that seeds have actual structures to assist in this process is shown by the careful examination of germinating seeds of mustard or radish. The root hairs are of a size possible to see with the unaided eye. The procedure: Place three or four thicknesses of colored blotting paper on two pieces of glass measuring about four by five inches. Wet the paper thoroughly and sprinkle dry mustard or radish seeds over it. Then place thin strips of wood around the edges of the blotting paper and fasten the two glasses together with bicycle tape. The seeds should fit loosely against the glass. Place the glasses in a warm place and observe at intervals for a week.

G. Flowers and their parts as functional structures.

1. To work out the uses of the yellow pollen cells characteristic of so many flowers, go through the steps involved in hybridization: Tie a manilla bag over a flower which is about ready to open. Find another flower in a similar condition of development, a plant of a related species, and from that flower take all the stamens. Tie a bag over it also. When the first flower opens, transfer by means of a small camel-hair brush, some of its pollen to the stigma of the stamen-less flower. Put the bag over the second flower again, placing a label on it.

2. The following procedure will show the pollen cells in the condition of having sent out pollen tubes: Three

sugar solutions of, approximately, 3, 10, and 15 per cent are made. Some ripe pollen cells from different flowers are shaken into these solutions. Upon several slides kept in a moist warm chamber for a day, a drop from each of these solutions separately, is placed under the compound microscope. Examination will show, in many cases, prolongations or root-like growths extending from the pollen grains.

H. Organic permeable membranes.

A vast number of experiments concerned with osmosis are possible. Of these many are very common while others work to a noticeable degree, and thus are useful. The suggestions below vary in their effectiveness. The variety of possible materials suggests many possible procedures. In all cases an entire membrane, or tissue, is covered on one side by one type of fluid, and on the other side by a fluid of different density. Difference in rates of diffusion produce a pressure sufficient to push a column of water upwards to a surprising extent. The experiments follow.

1. Place an egg in weak hydrochloric acid to eat away its outer shell. When this has been done, at least in several places, place this egg, and one of an equal size, in water for an hour. Examination will then show that the first egg has swollen extensively where its outer shell was removed. Apparently osmosis has occurred to cause this changed size.

2. Pick away the shell from the larger end of an

egg which has been in vinegar, carefully trying to do no injury to the membrane. When a piece of the membrane two inches square has been uncovered let the contents of the egg out at the smaller end. By means of several twists of a rubber band fasten the membrane over one end of a glass tube. Gently blow through the tube to find out if the membrane is entire. Discard the membrane if there are any holes in it. Then, allow a strong sugar solution (boiled) to seep down into the tube until the membrane is filled. Place in a tumbler of water so that the membrane is covered, but do not let it touch the sides or bottom of the jar. Fasten the tube to a ring stand. From time to time, take measurements of the level of the fluid in the tube.

3. With sealing wax, as seen in Figure 203, fasten a piece of glass tubing less than six inches long to the small end of a fresh egg. Be sure that the sealing wax allows no chance for leakage. When it is cool, carefully punch a hole in the eggshell by pushing a long pin or knitting needle through the tube. Now very carefully clip off some of the shell at the other end of the egg, taking care not to break the inner membrane. With a piece of rubber tubing fasten a long piece of glass tubing to the piece already stuck into the egg. Put the egg in water and support the apparatus firmly

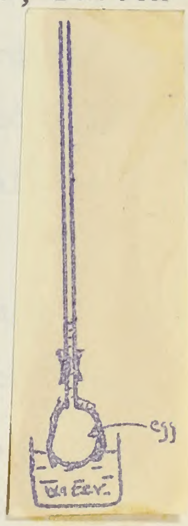


Figure 203. The usual osmosis procedure.

to a ring stand. Observe at regular intervals of fifteen minutes for two hours, less often, later; and measure changes as they are seen, for two days.

4. Remove the membrane or inside lining from an egg shell. Break an uncooked egg in halves and remove the yolk and egg white. Now break away a little of the shell around the edge to start the membrane. Using the thumb and forefinger pull it away from the shell very gently, bending it as far back on itself as possible. Hold the salvaged piece to the light. Do you see any openings? Set up the apparatus as shown in Figure 204 a thistle tube with a short stem and its mouth covered with egg membrane fastened with a rubber band. Put a trace of dark ink in a can of sugar solution and fill the bottle as indicated in the two diagrams. Take care air is kept out in both cases.

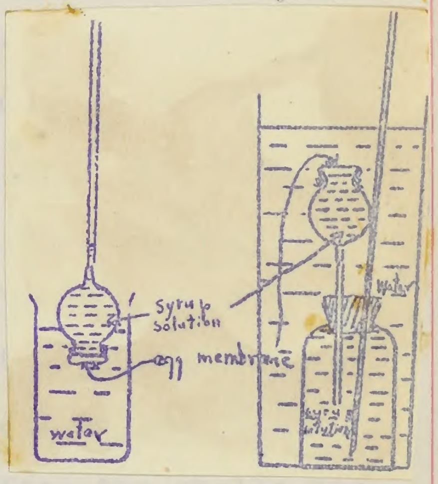


Figure 204. An egg membrane for osmosis.

5. Push the end of a long glass tube through a cork or rubber stopper making the hole with a cork-borer or sharp knife. Dig out the center of a carrot, potato, beet, or turnip, making sure that there are no holes in the walls of the root or stem, and making the opening the exact size of the stopper carrying the glass tube. Fill the hollowed center of the vegetable with the strong sugar solution and insert the

stopper and tube making it fit by filling all joints with sealing wax or paraffin. Then set it in a tumbler of clear water. Upon several occasions observe and note the level of the liquid in the long tube.

6. Cut three thin slices of a fresh beet. Place one in pure water, and one in salt water. Cover the third with dry salt and at the end of an hour compare the degree of flexibility of the three. Afterward, wash thoroughly the two pieces that were acted upon by salt, and set them in pure water for a day or two. Then observe.

7. Examine halves of different nut shells to see that there are no holes apparent. Use both halves of as many different kinds as are available. Keep the shells dry inside. Place a little granulated sugar in each using equal quantities per shell. Float one shell of each kind in pure water, and the other half-shell in strong sugar solution. Note the time when the last grain of sugar is dissolved.

8. Technique of getting egg membrane: Soak an egg in vinegar for three hours, when the egg will be sufficiently eaten to be removed without injury to the membrane.

An efficient membrane is that of the bladder of a pig, or other mammal. Slaughter houses provide these for the taking. Sausage skin, a frankfort skin, a gold beater's skin make good membranes, while white molasses, maple syrup, and honey are excellent sugar solutions.

9. A collodion sack is most excellent for osmosis experiments. In doing the experiment the sack is treated in the same manner as in the preceeding experiments.

To make the sack pour into a glass or glazed vessel 25 to 50 cubic entimeters of solution of collodion, pharmaceutical standard. This is an alcohol-ether solution of pyroxylin. Rotate the dish and pour out the solution while continuously turning the flask to uniformly coat the interior. Invert the flask to dry when the ether has evaporated and before the coating dries out soak the lining with water for 10 minutes. Cut the adhering film free from the exterior of the neck and pour out the water. To remove the bag allow water to run in between the film and the flask. Gently pull out the sack or lining. Fill it with water, dry it with a towel, and examine for perforations. Repair any holes by pouring out the water, drying the particular area and deftly touching a drop of the collodion solution to the hole. Preserve the membrane under water or 75 per cent alcohol solution until ready for use.

10. Capsules, of various sizes, used for medicinal containers, and made of gelatin are obtainable five for a nickel at a drug store. These can be used like the nut shells or the egg membranes.

A Few Laboratory Techniques
Used in This Chapter

A large illustrative chart of Mendel's Law data is very

useful in that connection.

A device to remove and possibly examine individual protozoa from a culture is shown in Figure 205. Due to capillary action at the jet, it is necessary to maintain a slight positive pressure until just the instant when the desired specimen is near the tube tip. If the jet itself is sufficiently fine, it may be taken for immediate examination in a compound microscope. A finely drawn eye-dropper jet, not quite as sensitive, will do.

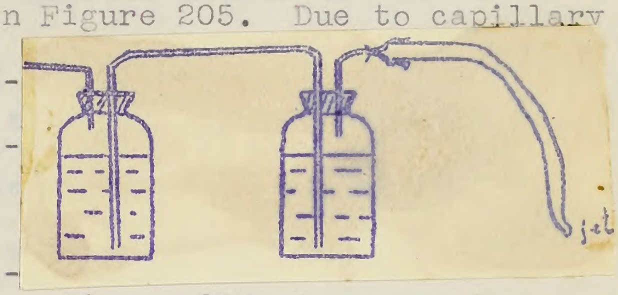


Figure 205. An extractor for protozoa.

Different types of stains make it easier to see microscopic specimens. The most commonly used is methylene blue, an aniline dye. With a little equipment and patience the general science teacher may build up a good set of slides.

Staining methods make it easy to see microscopic specimens:

1. Nitrogen fixing bacteria which fail to respond to ordinary aniline stains may be brought out by carbon-fuchsin and anilin-gentian-violet.

2. Sulphur bacteria may be stained with gentian violet and methylene blue.

3. Tuberculosis bacilli may be stained by the usual stains if heat is applied.

4. To stain animal (rat, turtle, or fish) tissue

nuclei use picric acid. Nuclei will be stained bluish purple; cytoplasm, yellow.

5. A special silver nitrate method to show structure of the cornea is: First, quickly rub a piece of silver nitrate over the cornea of an eye that has been removed from a recently killed frog or salamander. Second, slice off the cornea and place in distilled water. Brush surface with camel's hair brush. Third, expose to action of sunlight or strong daylight until tissue turns brown. Fourth, wash in distilled water; then, dehydrate and mount in balsam. The cells should be strongly outlined by the precipitated silver. (If desired nuclei may be stained in hematoylin according to the standard method.)

6. A good solution to clean tissues is made by adding 0.6 grams of sodium chloride to 100 grams of distilled water. This is for amphibia; for reptiles and birds use 0.75 grams of salt; for mammals 0.9 grams.

Culture-media suggestions are numerous. A few of the more promising types follow:

1. A potato agar is prepared by peeling and cutting about 250 grams (slightly less than 9 ounces) of potatoes, boiling them for one hour, and squeezing to a mush through muslin. To this add 20 grams, 3/4 ounce of agar; this is made up to one liter (about a quart). The operation of squeezing though the muslin is messy but supplies a good

quantity of cellulose. The container of the media is then plugged with cotton wool and heated to dissolve the materials. It is kept in test-tubes cotton plugged. The plugs are made by tightly rolling up strips of wool, and screwing them closely into the test tube so that they hold firmly. Sterilization may be done by steaming half an hour on three successive days to kill bacteria. The plugs must always be dry.

2. Malt agar is easier to prepare. To a liter of distilled water 20 grams of malt and 20 grams of agar are added. This is treated as is the potato media above.

3. Test tubes make good "slopes" as shown in Figure 206. The media is poured in and allowed to cool. The wool or cotton cap is used as a plug. Then before this is used, it must be sterilized in a bath of steam for three successive days using a half hour per treatment. On the last occasion the media is allowed to cool in the "slope" position. Other substitutes for the Petri-dish are plates which fit tightly over each other.

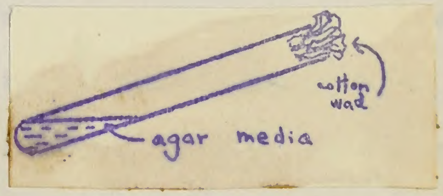


Figure 206. A Petri-dish substitute.

4. A culture medium can be made of several teaspoons of jello in a quart of water, enriched with a glass of beef broth and sufficient baking soda to neutralize the beef acid. This is heated until it is consistently clear throughout.

5. Another excellent food upon which bacteria can grow requires the following materials: two medium sized white potatoes, one half ounce of commercial gelatin, three eight-inch test tubes, (plugged with sterilized absorbent cotton wads), six Petri-dishes (covered), fine wire sieve or strainer, tongs, two-quart cooking pan and a clean towel and dish cloth. The potatoes are peeled, sliced and covered with little more than a pint of cold water. After bringing this to a boil and cooking for ten minutes, strain off a pint of the liquid and stir in gelatin, broken into small pieces. Set aside for ten minutes, then heat again until the gelatin is dissolved. Strain the liquid, pour it into test tubes until three-fourths full, and sterilize as follows: Place the Petri-dishes, covers, agar tubes (being careful not to wet plugs), and gripping end of tongs in the two-quart pan which contains about three inches of water at the bottom of which has been spread the towel or cloth. After the water has boiled for one half-hour the materials are ready for use. This has been found a simple and excellent way to sterilize the food material.

6. To prepare a bacteria garden: Put two petri-dishes on the table. Set two tubes of agar in a can of water and heat to liquify the agar. Burn the cotton wads, of the agar tubes, the remainder remove. Raise a cover of the Petri-dish, pour agar in quickly and carefully, and lower Petri-dish

cover immediately.

Seed testers make possible selecting the most fertile seed-producing plants.

1. Take a tall tumbler, a strip of blotting paper one and one-half inches wide, three soaked lima beans, and enough bulb fiber to fill the tumbler. Plant the beans between the blotter and glass. Fill the space on the other side of the blotting paper with moistened bulb fiber. Keep it moistened, not wet, in a warm part of the room.

2. Boil a piece of flannel about one and one-half inches wide and about four feet long. Mark off with indelible ink a series of squares on which place ten grains from each ear of corn numbered to correspond with the squares. The corn seed should be as fresh from the field as possible. Fold over the edges of the cloth and roll it up carefully, yet loose. Tie it loosely at the ends and in the middle. Soak it in water for twenty-four hours and then put it in warmth. Examine the contents every few days. Here, more accurately, percentage of fertility may be measured.

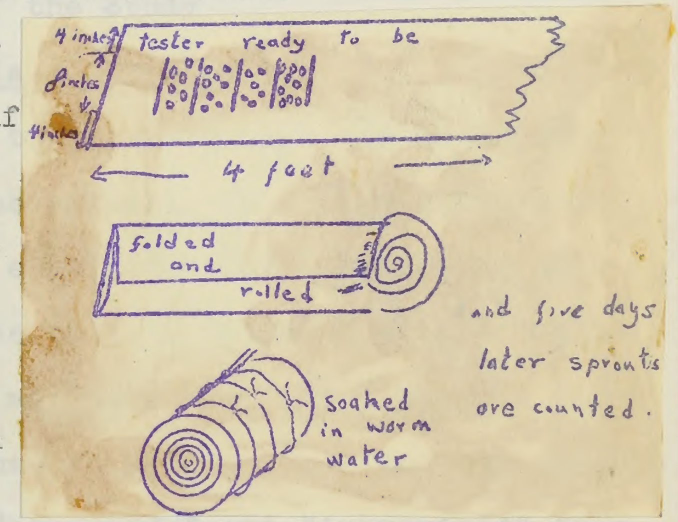


Figure 207. Another seed tester.

CHAPTER VI

CONCLUSION

Findings of the Study

A. <u>Nature of the materials included</u>.

It is to be admitted to the readers that the materials found in this paper may not be entirely in accord with their anticipations. That was not expected. They may not be able to justify the inclusion of certain to the exclusion of other ideas, and in some places it may seem that there has not been proper classification. It must be granted that any one person's interpretation of the words "home made" and "improvised" is a subjective opinion, and that what one person would classify under one principle another would classify differently. A great deal of this material may be very familiar to experienced science teachers. It is certain not to be as familiar to the younger and less experienced teachers.

Likewise, the writer is making no claim as to the completeness of this work because in any study such as this completeness is purely a relative matter. If this study furnishes a foundation for a better and more comprehensive study it will

not be unjustified. In the meantime, it is hoped that it may be of real value to the many teachers who are giving functional courses in general science.

B. Findings of the form letter.

Of the 114 persons answering the letter sent to all the senior high school principals in Massachusetts, 93 made suggestions and, for the most part, reflected opinion which proved of incentive to the writer in completing this work. Of the other 21 responses five were blank, eight indicated no information because the subject had been relegated to the junior high school, seven presented disapproving remarks, and one answer brought to light the fact that their endowment of half a million dollars had, until the last few years, been so fruitful as to make it possible not only to buy any equipment

Table 2. Opinion commending and discouraging the use of home-made or improvised apparatus in general science instruction.

Ideas commending use	Ideas discouraging use
(1)	(2)
1. Construction details come into the sight range of a larger percentage of a class.	1. There is insufficient time.
2. It is less expensive.	2. Factory-made materials are easier.
3. It provides experimental possibilities in the lack of laboratory facilities.	3. Many teachers lack training of the kind to enable them to make use of it.
4. It helps the overloaded teacher.	4. With the resulting loss in discipline and formality, the catering to the play spirit of such activities is questionable.
5. It increases interest.	
6. It brings problems closer to both teacher and pupil.	
7. It is more effective in learning.	
8. It provides opportunity for originality.	
9. It affords an opportunity for correlation between practical arts and general science.	

desired but also to make necessary a return to the fund of several hundred dollars annually. Table 2 summarizes the subjective opinion of these responses expressing the advantages and disadvantages to the use of the home-made and improvised in apparatus and materials.

C. Index of findings, by topics.

It is thought that the materials contained in this report will be more readily accessible if they are indexed. In this index are the names of the topics for which there are suggestions for the improvising of materials and for the constructing of apparatus.

Index

Recommendations of the Study.

A. Use of the materials.

Teachers who are just beginning their work in general science may have more use for this material than any other group. Any who have not been trained to teach this subject, or those who, in any other way, have been assigned this work to fill out their teaching responsibilities, could have considerable use for it. Those who have been teaching for some time may find a number of ideas with which to supplement the type of work they have been doing. Certainly instructors in schools where the condition of inadequate provisions of equipment prevails can find here suggestions of a valuable nature. In any case, a familiarity of these procedures by any science instructor might often furnish ideas for some activities concerned with a particular subject for the youngsters taking the general science course.

B. Recommendations for further study.

1. Some of the procedures herein listed are untested by the writer and in some of these cases there seems considerable doubt that the method described would satisfactorily demonstrate the principle involved, as for examples on pages 132, and 140, numbers eight and six, respectively. However, since the ideas were all found in reliable sources, it was thought reasonable to include them. An evaluation of these procedures in terms of their aptness for group-study use would be much worth while.

2. This work by no means covers the field. A wealth of challenging and instructive material is contained in the various popular and professional magazines. A contribution could come from this source alone.

3. A more definite arrangement is needed whereby pupils could find the time to manufacture these improvised pieces of apparatus. There are many opportunities for correlation between science and the shop activities, opportunities most of which are not indicated in this paper. Perhaps, the most valuable recommendation is that a course of study be worked up to bring out the numerous possibilities for the correlation of general science and the manual arts.

APPENDIX

APPENDIX

The sources of information other than as indicated in the bibliography, were, for the most part, those school people who made an answer to the form letter. This letter, a copy of which is to be found at the top of page 234, included the blank form shown on page 235, and was mailed to all of the high schools in Massachusetts. It was followed by a postal card which is copied at the bottom of page 234. Later, the report of the information furnished was distributed to all who indicated interest in receiving it. Accompanying this accumulation of material was a letter, a copy of which is to be found on page 236.

As was indicated before because of the doubt concerning the origin of the various ideas, and in order to yet mention the sources, it is thought necessary to present the list of all those answering the form letter. This list is presented from page 237-240, inclusive.

Heading

January Thirty-First
1 9 3 6

Inside address

Dear Mr. ---------:

Will you select one or more of your science teachers to cooperate in a study of the extent to which science teachers in Massachusetts are using procedures requiring home-made apparatus and materials in classroom work instead of those demanding expensive factory made products?

Experience for five years as an instructor in General Science has shown me that many of these original methods are actually superior to those using more expensive apparatus and material. This belief is the basis of a study of current original procedures.

I propose to summarize the data and in return for your cooperation I shall be glad to send you the results of the study.

Very truly yours

Science Instructor

Oxford, Mass.

Dear Sir:

Recently I took the liberty of addressing to you an inquiry about the improvised or home-made apparatus of your General Science classes.

I realize how busy you are and that you may not be interested in this study. To date, however, much of value has been returned. Do not hesitate to send in the seemingly simple procedures. They are often the most valuable.

I would very much appreciate an answer from your school.

Sincerely yours,

(THIS IS A SUGGESTED FORM FOR YOUR CONVENIENCE)

NAME.................................POSITION.................

SCHOOL...............................DATE.....................

PRINCIPLES DEMONSTRATED:

APPARATUS AND MATERIAL USED:

REMARKS:

Oxford, Massachusetts
March 13, 1936

Dear Sir:

I am enclosing again an envelope which I wish you would use in forwarding any further remarks, or better still in sending definite procedure suggestions which may occur to you as you examine those below. It is my feeling that many of the instructors have much of considerable value not called out by the first letter. Any additional methods of illustrating a principle will be of value to many teachers other than yourself and simple procedures of demonstrating ideas that were before omitted may occur to you. If there are such, will you kindly take a little more time to describe and diagram your methods. The diagram is even more important than the description.

At this time I wish to present to you the data, compiled from answers to letters sent out February first. This data, which is part of an investigation I am pushing in connection with graduate study assures me that many of the original procedures are actually superior to those using expensive supply-house materials.

Fortunately the validity of this report will not depend upon statistical compilation because the questionnaire form was purposely avoided. The desire here is to find as great a variety as possible of demonstrating a science principle. Personally, as an instructor of science subjects, I feel that my work is effective in the degree to which I reach the background of the members of the class. A variety of methods will enable me to reach this background more successfully than a single method.

Statistically, the report is a failure for only 79 out of the 253 letters have been answered. Several reasons for this are; to quote, "We do not have General Science in our high school... it is a ninth grade subject." Many by saying, "We do nothing of note," reflect the feeling that worth-while contributions must involve apparatus of imposing appearance. Replies, however, are still coming in and I hope I may hear more from your experience.

Sincerely yours,

Evan C. Richardson

Aiken, J. Hawley, Head of Science Department, Technical High School, Springfield
Alley, Otis E., Head of Science Department, Winchester High School
Andrews, Forrest, Science Instructor, Uxbridge High School
Andrews, Robert S., Principal, Pepperell High School
Archibald, Herbert H., Principal, Norwood High School
Ballard, K. C., Science, Lawrence Senior High School
Beede, M., General Science, North Quincy High School
Bridges, Frank L., Head of the Science Department, North Quincy High School
Brown, Max O., Teacher of General Science, Milton Junior High School
Buck, John H., Science Instructor, Wellesley Senior High School
Buckingham, Burdetted H., Physics Instructor, Quincy Senior High School
Burke, Arthur N., Principal, Waltham Senior High School
Burroughs, A. T., Science Teacher, Northboro High School
Bush, Alton W., Head of Science Department, Framingham High School
Butler, Richard, Head of the Science Department, Orleans High School
Caldwell, Ethel N., Science Teacher, Westford Academy
Card, Robert W., Science Department, Warren High School
Campbell, George P., Science Instructor, Marblehead High School
Carroll, Joseph O., Head of Science Department, Durfee High School, Fall River
Cavalieri, James, Teacher, Johnson High School, Ipswich
Chalmers, James A., Principal, Fitchburg High School
Chase, Isaiah, General Science Instructor, Merrimac High School
Chute, O. M., Principal, Sutton High School
Clark, John B., Principal, Williamstown High School
Clough, Henry P., Principal, Mendon High School
Cobb, Eben S., Principal, Clinton High School
Conant, Howard, Principal, Senior High School, Holyoke
Coulman, Arthur, Science, Winthrop High School
Danielson, Adah, Teacher, Killingly High School, Danielson, Connecticut
Davis, Osborne, Science Teacher, Belchertown High School
Delano, R. B., Junior Master, Memorial High School, Roxbury
Dexter, William A., Science Teacher, Williams High School, Stockbridge
Dockler, Henry E., Science Instructor, Gardner High School
Dubiel, Edward, Science Instructor, Wareham High School
Duruam, Walter T., Head of Science Department, South Boston High School
FitzGerald, C. A., Principal, High School, Chicopee

Fletcher, W. Roscoe, Physics, North High School, Worcester
Foster, Edward C., Head of Science Department, Williamsburg High School
Fowler, A., Head of Science Department, Arlington Senior High School
Gardner, John J., Teacher, Lowell High School
Garland, Oscar L., Head of Mathematics and Science Departments, Yarmouth High School
Gillespie, M. B., Science, Scituate High School
Gillmore, R. H., Principal, Hardwick,
Grayson, Herbert, Science Instructor, Holden High School
Green, W. Everett, Principal, Senior High School, Mansfield
Greenfield, M. Leroy, Principal, High School, Ware
Gula, Joseph, Science Teacher, Palmer High School
Hamblin, Nathan C., Principal, Punchard High School, Andover
Harris, Marion T., Science Teacher, Hopkinton High School
Hartford, A., Principal and Science Teacher, Medfield Junior and Senior High School
Hartwell, Edwin G., Science, High School, North Attleborough
Hathaway, Charles A., Head of Science Department, Taunton
Hill, William C., Principal, Classical High School, Springfield
Hirst, Helen G., Science Instructor, North Junior High School, Waltham
Holmes, C. W., Principal, Douglas High School
Horne, Grace A., Teacher, Millbury High School
Hatelius, Roland B., Vice Principal, Classical High School, Lynn
Ireland, Harold K., Head of Science Department, Greenfield High School
Jones, H. Norton, Science Teacher, Westfield High School
Kimball, W. F., Science Teacher, Story High School, Manchester
King, Hazel P., Teacher, Bartlett High School, Webster
Kipp, Walter D., Principal, Charlemont High School
Ladd, Harold, M., Principal, Brimfield High School
Leahy, John P., Head of Science Department, High School, Pittsfield
Lombard, C. W., Physics Instructor, Hyde Park High School
Lynch, Betty, General Science, Easthampton High School
Mank, Helen G., Head of Science Department, Lawrence High School
Mansur, Eric, Head of Science Department, Melrose High School
Marwell, Sumner E., Head of Science Department, New Bedford High School
Martin, Ralph J., Teacher of Chemistry, Physics, and Science, Medway High School
McDonough, Edward, Science, Prouty High School, Spencer
McMahon, H. J., Science Instructor, Southbridge High School
Meserve, Charles A., Head of Science Department, Sylvester High School, Hanover

Metcalf, Fred A., Instructor of Physics, Milford High School
Miller, Fred W., Principal and Science Instructor, Holliston High School
Morse, S. D., Principal, Brookfield High School
Mulgrew, William, Science Teacher, Blackstone High School
Packard, J. C., Head of Science Department, High School, Brookline
Parker, William E., Superintendent of Schools, Danielson, Connecticut
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Rhuland, Frank A., Science Teacher, High School, Beverly Hills
Riley, Clyde E., Science Teacher, Senior High School, Westboro
Ritter, George F., Head of Science Department, Cambridge High School
Sanders, Helen, Social Science, Princeton Center School
Shumway, Paul E., Chemistry and Physics, Turners Falls High School
Sisson, Jerome C., Instructor of General Science, Junior High School, Needham
Smith, William E., Science and Physics Teacher, The Boston English High School
Smith, C. C., Principal, Bartlett High School, Webster
Sumerville, Floyd E., Teacher of Science, Newton High School
Staples, Carl W., Head of Science Department, Chelsea Senior High School
Stedman, Harry P., Science Teacher, Dalton High School
Stegner, Freda B., Instructor of Science and Biology, Hitchcock Free Academy, Brimfield
Sussman, Rudolf, Head Master, The High School, Reading
Taylor, Robert N., Science Teacher, Oliver Ames High School, Braintree
Toolin, Paul V., Science Instructor, Braintree High School
Turner, Cornelius, Science Instructor, Leicester High School
Walkden, Charles E., Science Teacher, Joseph Case High School, Swansea
Welch, Louis, Junior Master, Dorchester High School for Boys
Wetherell, A. C., General Science, Auburn High School
Whipple, Ralph C., Principal, Ipswich High School
Whitehill, Edwin H., Head Master, Senior High School, Watertown
Wilder, Katherine, Chairman of General Science, John W. Weeks, Junior High School Principal, Newton
Willard, R. R., Principal, English High School, Lynn

Williams, F. Earl, Principal, Agawam High School
Wilson, Procter P., Science Department Head, Chelmsford High School
Woodbury, E. Davis, Science Instructor, Natick High School
Woodward, Edward, Principal, South High School, Worcester
Yates, Raymond, Science Teacher, North Attleboro High School

BIBLIOGRAPHY

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Sources Analyzed in Detail

Textbooks examined.

The following general science books received a detailed, careful examination with the purpose of selecting those suggested activities which seemed pertinent to this study.

The Science of Common Things, Samuel F. Tower and Joseph R. Lunt, D. C. Heath and Company, Boston, 1922. This is the oldest text to have stressed the importance of the activity more than the factual information contained. Its suggestions causing wonderment are about procedures using the home-made type of materials. Interest, and challenge concerning everyday materials are two of its excellent qualities.

Introduction to Science, Otis W. Caldwell and Francis D. Curtis, Ginn and Company, 1930. It stresses activity of simple types and experience of the "everyday" variety. An attempt is made to make pupils conscious of the so-called "scientific method". It is a superior book.

The World in Which We Live, Morris Meister, Charles Scribner's Sons, Boston, 1930. In the author's opinion this is the most challenging, interesting, and effective book in general science today. The major emphasis apparently is on the pupil's own activities and interests. This book provided more of the suggestions contained in this paper than any other single source.

Problems in General Science, George W. Hunter and Walter G. Whitman, American Book Company, Boston, 1930. This is a fine book. However, it seems too concentrated with information and too broad in the details of its scope to hold interest, and to be continuously challenging to the pupil reader. Many of its suggestions are contained in this paper.

General Science for Today, Ralph K. Watkins and Ralph C. Bedell, MacMillan and Company, New York, 1932. This book stresses pupil activity. One of its good qualities is that it does not go deeply into the details of a particular topic.

The Science of Everyday Life, Edgar F. Van Buskirk, Edith L. Smith, and Walter F. Nourse, Houghton and Mifflin, Boston 1933. This text has many suggestions of common place activities at the end of each chapter, many of which seem challenging to the reader.

Everyday Problems in Science, Charles J. Pieper and Wilbur L. Beauchamp, Scott, Foresman and Company, New York, 1934. The book arranged in what are called "units" considers a wide variety of everyday experiences. It contains excellent suggestions that can be simply worked out. It has a very broad scope and the details of experience considered are diverse.

Our Environment Series, Harry A. Carpenter and George C. Wood, Allyn and Bacon, Boston, 1934. This book offers a course through the Junior High School. In stimulating wonder and interest it rates highly.

Our Surroundings, Arthur G. Clement, Morton C. Collister, and Ernest L. Thurston, Iroquois Publishing Company, Syracuse, New York State, 1934. This text arranged by topics covers a broad field of experience much of which is common. The continual stress upon the factual could be improved by stimulation toward the activity movement.

Exploring the World of Science, Charles H. Lake, Henry P. Harley, and Louis E. Welton, Silver, Burdett and Company, Boston, 1934. The writers have made their title reveal its contents. It is a book for consciously exploring minds. Its scope is broad and its details, advantageously are not too involved.

A Learning Guide in General Science, Philip Boyer, Arthur S. Clark, Hans C. Gordon, and John Shilling, Lyons and Carnahan, Boston, 1935. There is little emphasis here upon the factual. It is an excellent book to use in tutoring a person who has the time to get his science knowledge from the experiment process. It is a book for superior pupils.

Magazines examined.

Two popular science magazines received a careful examination with the same purpose in mind as that which applied to

the textbooks examined.

Popular Science Magazine, Popular Science Publishing Company, Inc., New York City, September, 1932 to June, 1933.

Popular Mechanics Magazine, Popular Mechanics Company, Chicago, October, 1934 to December, 1935.

Other Sources

The Science Masters' Book, John Murray, Albemarle Street, London, 1931. This text can be purchased from G. E. Stechert & Company (Alfred Hafner), Booksellers & Importers, 31 East 10th Street, New York City, for $2.25 per volume plus postage.

General Science, R. C. Hodgdon, D. C. Heath and Company, 1918. An elementary science book which has numerous examples of unique improvised apparatus. On pages 10 to 16 are descriptions of simple barometers and hygrometers.

Lois Meier, "Teaching Science in the Seventh and Eighth Grades", General Science Quarterly, 10: 37-46, November, 1924. This author in this article heartily endorses a functional course for the Junior High School science. The article was filled with description of simple demonstrations which seemed to have much instructional value.

Hans Overn; Joseph Iler, and Heine Heineman, "Analysis of Textbooks in General Science", General Science Quarterly, 10: 563-568, May, 1928. They found that it is the rare exception for one author to treat all the subdivisions of any major topic. Such a task would qualify the work as an encyclopedia rather than a textbook of science.

George E. Underhill, "Homemade Apparatus", General Science Quarterly, 13: 147-153, March, 1929. He describes the summer school class which he, at that time, had recently conducted at Hampton Institute. In this class the members, teachers, made an attempt to learn something of the techniques which are useful in making one's own apparatus. The course, has now been discontinued. Doctor Underhill is now an instructor at the Conneticut State Teachers' College at New Britain.

Edmund S. Obourn, "The Effective Use of Practical Equipment in a Physics Course", School Science and Mathematics, 28: 275-280, November, 1928. It describes work with the improvised apparatus in the topic, mechanics.

G. H. Hyde, "Homemade Apparatus for the Physics Class", Science Education, 15: 159-174, March, 1931.

G. H. Hyde, "An Annotated Bibliography of Contributions to School Science and Mathematics Describing Inginious and Homemade Physics Apparatus", School Science and Mathematics, 29: 763-769, May, 1929. This provides a short cut to find a description of curious procedures in a particular interest.

Catalogue H351, Central Scientific Company, Chicago, 1935-1936.

Morris Meister, "Recent Educational Research in Science Teaching", School Science and Mathematics, Volume 32, 1932, pp. 881-884.

Physical Experiments, Woodhull and Van Arsdale, a laboratory manual, D. C. Appleton and Company, 1900.

Laboratory Projects in Physics, F. F. Good, D. C. Heath and Company, 1915.

School Science and Mathematics, a journal for all science and mathematics teachers, published by the Central Association of Science and Mathematics Teachers, all issues 1931 to 1933, inclusive.

Journal of Chemical Education, published by the Chemical Education division of the American Chemical Society, Easton, Pennsylvania, issues of 1928.

Home-made Apparatus, C. H. Lombard, a graduate thesis, Boston Teachers' College, 1933.